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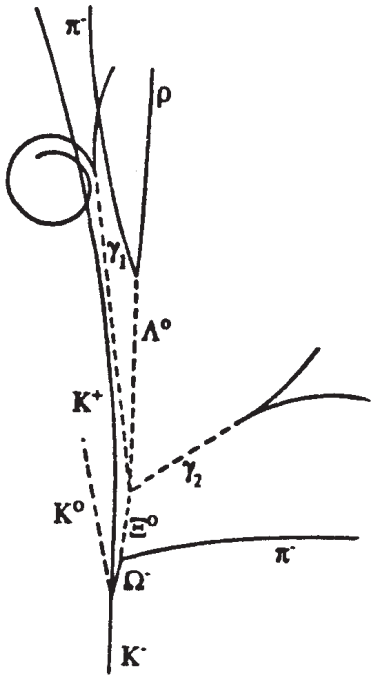

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INTERPRETATION OF GRAVITY, 329
Bertrand Wong
Department of Science and Technology
Eurotech, Singapore Branch
EXPANSION FORCE AS A CONSEQUENCE OF BOHMIAN QUANTUM MECHANICS, 343
Jacques Fleuret
Telecom Paris Tech
33 rue des Roses
92160 Antony, France
NEW RESEARCH AND DEVELOPMENT OF UNCERTAINTY RELATIONS, 357
Yi-Fang Chang
Department of Physics
Yunnan University
Kunming, 650091, China
THE RELATIONSHIP OF DENSITY WITH THE SIZES OF ATOMS AND THEIR NUCLEI, 379
F. F. Gorbatsevich
Geological Institute of the Kola Science
Centre of the Russian Academy of Sciences, Apatity
TIME AND THE QUANTUM PART 1; TIME-ONLY PHYSICS, 387
Graham Andrews
15924 N. Azure Dr.
Spokane, Washington 99208
TIME AND THE QUANTUM PART 2; WHENCE THE QUANTUM?, 409
Graham Andrews
15924 N. Azure Dr.
Spokane, Washington 99208
NEW THERMODYNAMICS: QUESTIONING TEMPERATURE IN OPEN SYSTEMS, e.g., IN ATMOSPHERIC PHYSICS, 431
Kent W. Mayhew
68 Pineglen Cres.
Ottawa, Ontario, Canada K2G 0G8

INDEX VOL 44, 2021.....445

HADRONIC JOURNAL 44, 329 - 341 (2021)
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INTERPRETATION OF GRAVITY

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Abstract

Gravity was discovered accidentally by Newton after he observed an apple falling from a tree. But what actually is gravity and what is its role in nature? However, gravity remains much of a mystery. We experience gravity and are affected by it all the time, and yet we do not know what it really is except for interpreting it as a force or field. This paper takes on the challenging task of examining gravity and suggesting the possible actual role of gravity in nature, from our macro-world to the micro quantum world, and hence the possible unification of gravity with all the other forces of nature, through two modes of reasoning, namely reasoning by *reductio ad absurdum* and by analogy. The paper contains preliminary and explanatory materials which lead to the author's hypotheses in Sections 5 and 6; Section 6 also provides some anecdotal evidence of what gravity is.

Keywords: gravity, forces of nature, space-time, geodesic, dimensions, supersymmetry, gravitons, unification

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1 Overview

Einstein had expended great effort to unify the four forces of nature, namely, gravity, weak nuclear force, strong nuclear force and electromagnetism, but had failed. He had purportedly tried to make use of a set of 16 complex tensor equations, the combinations of ten of which representing gravitation and the remaining six representing electromagnetism, with the concept that a pure gravitational field could exist without an electromagnetic field but a pure electromagnetic field could not exist without an accompanying gravitational field. He was not able to derive the electromagnetic field equations, even for the weak-field approximation, and had no success at all with the unified field theory.

Einstein had hypothesized that gravity is the geodesic of an "imaginary rubber sheet" which occupies space in his paper on general relativity. He had thereby transformed the abstract entity, gravity, into a geometric, more tangible entity that is linked to space-time, which had evidently been an attractive concept to his peers. How should this "rubber sheet" be visualized or interpreted? Is this "rubber sheet" really three-dimensional as has been illustrated by pictures in scientific tomes, or, is it of more dimensions? It is thought that since we are only able to move around in the three large dimensions of length, breadth and height, which are observable, and the time dimension, all other dimensions would have to be very small and invisible to us, curled up in a multidimensional space which could be regarded as representing the invisible micro-world of the quantum particles. This is in line with the concept of the unified field theory which concerns combining General Relativity and quantum theory.

Einstein had believed that David Bohm would be the first to solve the unification problem. However, the latter treated the unified field theory problem lightly, regarding it an "illusion of parts", simply relegating it to the logical constraints of topology and interpreting the universe in a metaphysical way as the "looking-glass" universe. [1] Bohm hypothesized that the unified field theory is based on the illusion of parts (gravity, strong nuclear force, weak nuclear force and electromagnetic force) and is a futile problem; the observer is the observed, the part is the whole, which all seems more metaphysics than physics, this evidently having been the state of physics. He believed that unification could be achieved through the use of the logical relations of topology. [2–4]

2 Gravity, Quantum Particles and General Relativity

There is still a lot of mystery surrounding gravity. Though the effect of gravity is well evident in our macro-world, it seems to have hardly any effect on the quantum particles in the micro-world, the quantum particles apparently whizzing about freely and without the constraint of gravity there, which seems to imply that gravity may not exist in the quantum world.

Unlike the objects in the macro-world, quantum particles in the micro-world are relatively unpredictable in their actions or movements and can only be predicted in a probabilistic fashion if at all. We will never be able to know for certain where a quantum particle will turn up next. Moreover quantum particles are capable of being at two different places at the same time, and, also capable of instantaneous travel or teleportation, which is "spooky" and incomprehensible, and evidently in defiance of gravity – this phenomenon is known as quantum entanglement. We can have a quantum field equation involving infinite dimensions. According to modern quantum mechanics, all possible physical states of a system correspond to space vectors in a Hilbert space. An infinite-dimensional Hilbert space ties up with the theory of the existence of an infinite number of parallel universes connected with each other through worm-holes. [5]

The Schrodinger equation in quantum mechanics, [6,7] which is as follows, can be applied to any physical system in which the mathematical form of the energy is known:-

$$\frac{\partial^2 \Psi}{\partial x^2} + \frac{8\pi^2 m}{h^2} (E - V) \psi = 0 \qquad (1)$$

∂^2 above is the second derivative with respect to x, x is the particle's position, ψ is the Schrodinger wave function, or, the probability amplitude for an electron in the state n to traverse in another direction, m is mass, E is energy and V is potential energy.

The Schrodinger equation describes nature in a deterministic time-symmetrical way. In classical mechanics, when it is pointed out that a quantum system is in a certain "state", it means that the state is a point in phase space. [7] This could be described by a wave function whose evolution over time is expressed by the equation shown below:-

$$ih / 2\pi \, \partial\psi (t) / \partial t = H_{op} \psi (t) \qquad (2)$$

The above equation identifies the time derivative of the Schrodinger wave function ψ with the action of the Hamiltonian operator on ψ. It is assumed at the start and is not derived, and can therefore be validated only by experiment. It is the fundamental law of nature in quantum theory. ψ here is the probability amplitude for an electron – it has no physical reality, being only an abstraction. ψ is also, in a way, the intensity wave of the electron. It is a physical probability of the presence of the associated particle when it is squared and the absolute value is obtained.

The square of the normalized amplitude of the individual wave function, that is, ψ^2, represents the probability of the existence of a state. This was another new idea, namely, the probability that a particular quantum state exists. There are no more exact answers in quantum theory, only probabilities. The wave Ψ determines the probability that the electron will be in a particular position, and, unlike the electromagnetic field, it is only an abstraction, that is, it has no physical reality.

Light can be regarded as particles or waves. In quantum mechanics, particles are in fact considered waves. How these particles behave can be predicted, these particles being known as probability waves or Dirac wave particles, which have a wave/particle duality. [8] When the particle is not observed, it stays as a probability wave, but on being observed it becomes a particle.

The following is the formal solution of the Schrodinger equation:-

$$\psi(t) = U(t)\ \psi(0) \qquad (3)$$

where $U(t) = e^{-iHt}$, $U(t)$ is the evolution operator which links the wave function's value at time t to that at the initial time $t = 0$. Both future and past play the same part, since $U(t_1)\ U(t_2) = U(t_1 + t_2)$, whatever the sign of t_1 and t_2. This property results in a dynamical group. [9]

The moot question is: Does gravity affect the particle whose motions are probabilistic and not easy to predict?

Gravity is crucial to the formulation of a unified field theory and can be described by the following formula:-

$$F = G\frac{M_1\ M_2}{R^2} \qquad (4)$$

where F is the gravitational force of attraction, G is the gravitational constant, M_1 and M_2 are the masses of two objects and R^2 is the distance between masses.

Prior to Newton's discovery, nobody had known gravity existed or had thought that there was such a force. In the General Theory of Relativity Einstein interpreted gravity as a curvature of the space-time continuum, a geometrical form. Can gravity be the fifth dimension, in addition to the four dimensions of length, breadth, height and time as per General Relativity?

Gravity is apparently a weak force in nature, making its detection via gravitational waves in our macro-world very difficult. It could possibly be an aspect of the electromagnetic field (which comprises of an electric field and a magnetic field, wherein one mass attracts or repulses another mass and pulls or pushes the latter towards or away from itself), for example, magnetism, or, it could be another field by itself, namely, the gravitational field with its own particles which may be called gravitons.

In 1905, Einstein in his Theory of Special Relativity introduced the gravitational force which was considered responsible for the orbits of planets, as was described by Newtonian gravity wherein gravity was an instantaneous force which propagated through space infinitely fast and was evidently at odds with Einstein's Theory of Special Relativity which posits that nothing can exceed the velocity of light.

Einstein in his General Theory of Relativity published in 1915 introduced a new theory of gravity which was compatible with the special theory. The space-time continuum was introduced in this new theory wherein empty space was likened to a flat rubber sheet which was flexible – a massive object creates an indentation in this empty space, or, "rubber sheet" – this indentation is hence interpreted as an effect of gravity, a curved space-time, a geometry. In fact, in this new theory massive objects determine how space-time curves. The connection between the mass of an object and the space-time curvature can be worked out, this being encapsulated in Einstein's all-important "field equations". Einstein was thus finally able to bring gravity in line with relativity. Below is Einstein's equation for General Relativity:-

$$G_{im} = -\mathbf{K}(T_{im} - 1/2g_{im}T) \qquad (5)$$

This beautiful equation expresses the curvature of space-time. The left-hand side of the equation represents a set of terms which characterise the geometry of space, while the right-hand side represents a set of terms which describe the distribution of energy and momentum; in other words, the left-hand is the

geometry side, while the right-hand is the matter side. Viewed from left to right is space-time directing mass how to move, while viewed from right to left is mass directing space-time how to curve. In General Relativity, absolute time or space does not exist, and, gravity is a property of space and time and not a force, or, pull between one object and another. All this is a great conceptual leap of Einstein. There is no basis in reality for the coordinate system of Einstein's General Theory of Relativity, which is only a mental construct used to describe the space-time continuum of the General Theory of Relativity. [2,3]

Gravity has always been considered a pulling or attracting force, similar to the force of attraction between two magnets. Gravity and magnetism are possibly different aspects of the same thing. Gravity so far is seen as a force of attraction only whereas magnetic and electric forces are forces of attraction and repulsion. There is possibly a gravitational force of repulsion. Gravity and electromagnetism could be linked resulting in anti-gravitational force and/or torsion in space-time. There may be an anti-gravitational force for every gravitational force, similar to the existence of an anti-particle for every particle. Anti-particles may be ordinary particles traveling backwards in time, implying that anti-particles should have anti-gravity. The electromagnetic and gravitational force-fields could possibly combine to give motive power. All this will affect our approach towards the unification of the four forces of nature.

Quantum particles appear free from the effect of gravity, which seems only to have a negligible effect on them, unlike in the macro-world. On the other hand, gravity could be totally different from what it had been thought to be, thereby possibly rendering unification with the other three forces impossible.

3 Supersymmetry

According to Einstein's theory of gravity, the graviton, the hypothetical quantum of gravity, which is a spin-2 boson, interacts very weakly with other matter, much more so than neutrinos, so weak that no instruments have been able to detect it so far. In the supergravity extension of this theory of gravity, the graviton locates a superpartner, the gravitino, which is a spin-3/2 fermion. These two particles transform one into the other, under local supersymmetric transformations. When quantum calculations were done using supergravity theory, it was found that the infinities which plagued the earlier gravity theory with only the graviton were now being cancelled by equal and opposite infinities caused by the gravitino. This is evidently due to the deeper

consequence of the presence of supersymmetry. This "softening of the infinities" is apparently a step toward a viable theory of quantum gravity, though it is uncertain whether the supergravity theory is totally renormalisable. It hardly matches or reflects the real world with its many particles as simple supergravity theory includes only the graviton and the gravitino. It is evident that some critically important idea is still missing. Due to the absence of this critically important idea, the theories simply do not describe the real world.

How can supergravity theory be made realistic? If this problem can be solved, supergravity theory can be a completely unified field theory. The principle of local supersymmetry is evidently very restrictive, with only eight possible supergravity theories that are each labeled by an integer N = 1, 2 . . . 8. Supergravity theory and the Theory of General Relativity have the same features, namely, conceptual power and mathematical complexity. Possibly, by positing the existence of a single master supersymmetry a unified field theory which accounts for the whole universe can be achieved. [10–12]

4 String Theory

In string theory, gravity is regarded as a vibrating string which vibrates at a certain frequency, while all the particles which are to unite with gravity are each also a string which vibrates at a certain vibrational pattern (a string's vibrational pattern determines its mass and charge). However, for the theory to work, ten dimensions, nine of space and one of time, are needed; this is because if the number of space dimensions is less than nine the number of vibrational patterns would be too small, the smaller the number of space dimensions the smaller would be the number of vibrational patterns, but with nine space dimensions the constraint on the number of vibrational patterns is perfectly satisfied.

String theory has been considered a good candidate for success at unification. [12,13]

5 Methodology for Deriving New Angle on Space-Time and Geometry

There is indeed a striking similarity between the macro-world of planets and the micro-world of quantum particles, namely, that while the planets orbit in ellipses round the sun in the macro-world apparently under the effect of gravitational pull, electrons orbit round the nucleus in the micro-world (perhaps also under the effect of gravity). We would show that there is the

reasonable possibility that gravity is a fluid, with some anecdotal evidence of this described in Section 6, the conclusion.

Gravity is possibly a fluid (similar to fluids such as air, liquid and gas) pathway or guide-rail (a geodesic) which directs or guides the natural movements of the larger objects in the macro-world and miniscule quantum particles in the micro-world, as per the curved space-time "rubber sheet" concept of Einstein – a geometrical, hence more tangible, non-quantum object, which is in accordance with Einstein's equation for General Relativity below, whereby reading from left to right is space-time telling mass how to move, while reading from right to left is mass telling space-time how to curve:-

$$G_{im} = -\mathbf{K}(T_{im} - 1/2 g_{im} T)$$

which could be further generalized by the following field equations of Einstein:-

$$G_{uv} + g_{uv} A = \frac{8\pi G}{C^4} T_{uv} \qquad (6)$$

where:

G_{uv} represents the curvature of space-time

g_{uv} represents the structure of space-time

A (lambda) is the cosmological constant, a term which could describe a repulsive force throughout space – this term, represented by the Greek letter lambda, had been included by Einstein in his general relativity equations which describe how matter and energy bend space-time; [14] A (lambda) might be the result of vacuum energy, the energy in empty space, made of "virtual particles" – pairs of particles and anti-particles which constantly appear and disappear, wherein the particles and anti-particles inter-act and annihilate each other; in turn A (lambda) might cause dark energy which is the force responsible for the acceleration of the expansion of the universe resulting in galaxies flying apart

G is the gravitational constant

T_{uv} represents the energy and momentum of matter and radiation

C is the speed of light

The ideas which follow are an important extension of this concept of Einstein, already explained in Section 2 above, a new angle of the concept – the explanation of gravity as a fluid would be provided.

First, we use the reasoning by *reductio ad absurdum*, that is, reasoning by contradiction. It is probable that Einstein had also entertained the concept of gravity as a fluid but had instead likened empty space to a flat rubber sheet which was flexible, wherein a massive object creates an indentation in this empty space, or, "rubber sheet" – this indentation interpreted as a gravitational effect, a curved space-time, a geometry, as this apparently metaphorical way of explaining gravity by treating it as a "rubber sheet" (which is two-dimensional, while the indentation in it by a massive object would make it three-dimensional) would make his concept of gravity as curved space-time more easily visualized and understood. As the objects in nature are countless and innumerable, this implies that the number of "rubber sheets" (which are basically two-dimensional) or "layers" required to "guide" the movements of the countless and innumerable objects in nature would also be countless and innumerable. The reader could probably imagine these countless and innumerable "rubber sheets" clashing and entangling with each other with possibly catastrophic results for the countless and innumerable objects in nature. The "rubber sheets" represent multiple, countless, innumerable and *discontinuous* "layers" which occupy space. All this depiction of the "rubber sheets" occupying space does not appear to give a true, accurate or sensible picture of nature, that is, this depiction of space-time appears a point of absurdity or ludicrousness which implies that it could not be the truth or fact. On the other hand (that is, by contradiction), if all the countless and innumerable "rubber sheets" were replaced by a fluid, which has *continuity*, there would be only *one continuous "layer"* in nature to "guide" the movements of the countless and innumerable objects in nature, which makes more practical sense; it would evidently be easy to visualize the objects of nature moving smoothly and without difficulty through a fluid, such as water or air, instead of through "rubber sheets". It is thus likely that Einstein had adopted the concept of the "rubber sheets" only as a simplification and

metaphor for describing gravity, as is stated above. [15] Hence, by *reductio ad adsurdum* or contradiction it is shown that the concept of gravity being a fluid is a credible or reasonable one. We progress from here to reasoning by analogy below and to describing the anecdotal evidence that gravity is a fluid in Section 6, the conclusion, which further shows the credibility of gravity as a fluid.

Gravity could be regarded as the medium or carrier-wave all massive objects in the macro-world and all quantum particles in the micro-world travel in, similar to the case of sound or vibrations travelling through air or liquid which become the media for their transmission, or TV or radio signals being carried by carrier waves over very long distances. Gravity may even be regarded as the analog of the theoretical luminiferous ether, the medium by which light has been thought to travel.

As a fluid, flexible medium, like air, liquid or gas, gravity thus possibly links the macro-world of planets and the micro-world of quantum particles (through what may be described as a fluid space-time continuum). For example (as an analogy), liquid (and even air or gas) would fill up any empty space it encounters, from the seas and rivers, etc. (macro-world), to the tiny capillaries (micro-world) in soils, rocks, etc., even moving or washing away some of the soils, rocks, and any other objects in its way. That is, gravity could be reduced to this fluid geometrical form, similar to liquid, air and gas.

What we see as the effects of gravity could be analogous to how objects of different densities behave, for example, when immersed in liquid, denser objects would settle to the bottom of the liquid (in fact very quickly so if the object is very dense) while the less dense objects would be suspended nearer or at the top (like the denser objects which sink to the sea-bottom while the less dense objects float nearer or at the top of the ocean), also, look at the case of objects falling or rising in the air, for example, solid rocks falling down through the air and helium-filled balloons rising in the air. Consider further the case of the falling rocks as an interesting example: The strength of the gravitational field (g) affecting the falling rock is considered equal to the acceleration (a) of the falling rock under its influence, wherein the value of g is as follows:-

$$g = 9.80665 \text{ m/s}^2 \ (32.1740 \text{ ft/s}^2)$$

If the falling rock is thrown down with a force, according to Newton's second law, the rate of change of momentum p of the falling rock equals the total force F acting on it, as is described by the following equation:-

$$F = \partial p/\partial t \qquad (7)$$

If, as is normally the case, the mass of the falling rock is constant, $F = \partial(mv)/\partial t$ reduces to $F = m\partial v/\partial t$ or $F = ma$, where a is the acceleration of the falling rock, the force (F) and acceleration (a) being vectors.

However, as is explained in Section 2 above, in General Relativity, space and time are not absolute, and, gravity is a property of space and time and *not a force, or, pull between one object and another*, which is opposed to the example of the falling rock immediately above. As for the case of outer space and other planets such as the moon, the possibly denser fluid gravity there may allow astronauts to float in it, which could be interpreted as the "lesser effect of gravity". The suspension, floating and orbiting of the planets in outer space (which is comparable to birds/objects suspended/floating freely in the air and fishes/objects suspended/floating in water in the sea), apparently under the influence of gravity, is possibly a manifestation of the above-described phenomenon.

Just as waves could be detected in liquids and air, it is thought that gravitational waves could be detected. But since gravity is considered a very weak force the detection of gravitational waves would be very difficult.

The other important point to consider is on the make or composition of the above-mentioned gravitational fluid which possibly exists. What would this possibly existent gravitational fluid be composed of? Could it be made of air, liquid or gas, or a combination of some or all of the three? Could it be composed of some element or elements, or, particle or particles, which may be waiting to be discovered? The theoretical graviton may be a potential candidate but it has been regarded as a quantum particle whereas this gravitational fluid aka curved space-time is non-quantum. [16]

6 Conclusion

It could be concluded that gravity is either a geometrical, non-quantum entity (as is explained in Section 5 above wherein gravity is shown to be a fluid) or a quantum entity (the quantum of gravity having been labeled as graviton).

Though there are a number of interpretations of gravity, only one of them could possibly be the correct interpretation, which has also to be successfully confirmed by empirical evidence, and that is apparently a great problem,

gravity being apparently such a weak force and hence very difficult to detect; gravitational waves would be very difficult to detect even with advanced scientific equipment which may not be sensitive enough to detect them, and, if gravity were indeed a quantum force like electrons, for example, the detection of its quantum particles, namely, gravitons, would also be very difficult. However, the unification of gravity with all the other forces of nature could possibly be achieved by one of the above-mentioned ways.

The search for gravitational waves is still ongoing. The existence of gravitational waves so far is inconclusive – there is only indirect evidence of their existence. In frame dragging, which is a gravitational effect, objects occupying the space close to a rotating object are swept around with it; rotating objects drag space around with them like the effect of a spoon in motion in treacle (syrup), *which appears to corroborate the theory that gravity is a fluid (analogous or similar to treacle (syrup), which is also a fluid), which is explained in Section 5 above.* Scientists studying the data from two Earth-orbiting satellites in 2004 apparently discovered evidence of frame dragging – they claimed to have found the minute frame dragging effect of our planet. Useful energy could possibly be extracted from the rotation of our planet, which could be a power source for an advanced civilization.

Gravity has so far been regarded as an attracting or pulling force. But couldn't gravity be possibly a pushing force instead, which is the equivalent of the attracting or pulling force? For example, a door could be closed by someone *pushing* it out from the inside, or, someone *pulling* it out from the outside (or, vice versa, someone *pulling* it in from the inside, or, someone *pushing* it in from the outside), with the same "closed door" result. This different way of looking at gravity deserves some consideration.

Unification should result in an equation which would connect the visible macro-world with the invisible micro-world of the quantum particles, which would link gravity with the weak nuclear force, strong nuclear force and electromagnetism, an equation that should contain all the information about the universe. This unified theory may also be called the theory of everything (TOE).

Finally, we conclude that there is the reasonable, credible possibility that gravity is a fluid.

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EXPANSION FORCE AS A CONSEQUENCE OF BOHMIAN QUANTUM MECHANICS

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Abstract

I proposed a new expansion force to explain Universe expansion without Dark Matter.

In this paper, it is shown that this force can be deduced from Bohmian Quantum Mechanics, introducing a bridge between QM and Astrophysics.

This approach could clarify the present questions about the Hubble « Constant » measurements and give information about the real mass content of the Universe and its repartition.

KEYWORDS

Bohmian Quantum Mechanics; expansion; Hubble Constant; Universe homogeneity; negative mass.

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1. Introduction

As is well known, the two fundamental theories of physics are based on quite different postulates: continuity and determinism for Relativity, quantification and hazard for Quantum Mechanics. It is also known that De Broglie and Bohm [2] [5] developed the pilot wave theory, which has the advantage to avoid intrinsic hazard in science [1] [6] [17]. It is surprising in my opinion that this approach is only considered by a small part of the scientific community [13] [22].

Anyway, both theories have developed an impressive amount of results. In particular, cosmology – mostly based on Relativity – has produced a lot of knowledge about the universe, with the ΛCDM model. But this "knowledge" is based on the quasi totally unknown Dark Matter in particular. I have proposed a new approach to avoid the Dark Matter hypothesis [7]: a new expansion acceleration should be added to the Newtonian attraction. I have shown that it can be considered as a solution of the Einstein equation for a particular metric [9] and applied it to the study of a non necessarily homogeneous universe. According to this theory [10], the universe should not be "expanding by himself" (with a scale factor), but the expansion force would act on each particle, "expanding" its movement, in a new dynamics principle.

For our present point of view, it will be sufficient to restrict our attention to a radial movement. In this case, the expansion acceleration has the form:

$$\gamma_{exp} = \frac{\dot{r}^2}{r} \tag{1}$$

In this paper, I propose that **this acceleration could be due to a Bohmian Quantum effect**. For this purpose, the differential equation is first established for a particle moving with its pilot wave in a Newtonian potential. Then, this is applied to the radial movement of a far-away galaxy submitted to the Newton's attraction from all other masses. It is then shown that **the additional expansion force is a consequence of quantum Bohmian Mechanics**. Then are examined the cases of a uniform Universe and a non homogeneous one. In this case, a possible validation test can be envisioned by the analysis of the present Hubble "Constant" measurements.

2. Bohmian particle dynamics in a Newtonian potential

Let-us consider a particle of mass m, with its pilot wave ψ (supposed to be Gaussian).

It is supposed to be in the outskirt of the universe, in such a way that the influence of all other masses can be considered as if they were concentrated in a total mass M(r), where r is the distance measured from the observer.

[In Bohmian dynamics, this mass M should have a pilot wave, and the global pilot wave should be the sum of the two. But the "particle" is so small when compared to the total mass of the universe - even if it is a far-away galaxy - and it is so far away that its global influence to all other masses can be reasonably neglected, in such a way that the pilot wave of the central mass M disappears in the total pilot wave to be considered.]

The problem is thus reduced to the behavior of the "particle" with its pilot wave in an "empty" space with a central attractor M(r). Let-us focus our attention to radial movements. It is then a 1D problem. Let-us call r the position of the particle. Since, according to the Gauss theorem, the Newton's acceleration is the same as produced by the total concentrated mass M(r), the acting potential can be written as:

$$V(r) = -\int -\frac{M(r)G}{r^2}dr \tag{2}$$

Let-us assume that the initial pilot wave of the "particule" is described by the following (normalized) gaussian packet of width Д:

$$\psi(r, t=0) = \frac{1}{(2\pi Д^2)^{\frac{1}{4}}} e^{-\frac{r^2}{4Д^2}} \tag{3}$$

The Fourier components of the initial wave are given by:

$$\varphi(p, 0) \sim \int e^{-\frac{r^2}{4Д^2}} e^{-\frac{ipr}{\hbar}} dr \tag{4}$$

Each plane wave $e^{-i(\frac{pr}{\hbar} - \omega t)}$ (5)

evolves with time and satisfies the Schrodinger equation, leading to:

$$E = \hbar\omega = \frac{p^2}{2m} + V \tag{6}$$

From (5) the time evolution of the wave can be computed as:

$$\psi(r, t) = \int \varphi(p)\, e^{\frac{ipr}{\hbar} - i\frac{p^2 t}{2m\hbar} - i\frac{Vt}{\hbar}} dp \tag{7}$$

This can be integrated and normalized [4] to give:

$$\psi(r,t) = \frac{1}{\left[2\pi Д^2\left(1+i\frac{t}{\tau}\right)\right]^{\frac{1}{4}}} e^{-\frac{r^2}{4Д^2\left(1+i\frac{t}{\tau}\right)} - i\frac{Vt}{\hbar}} \tag{8}$$

where the time parameter τ has been introduced:

$$\tau = \frac{2mД^2}{\hbar} \tag{9}$$

Finally, the Bohmian solution for the particle dynamics is given by:

$$\frac{dr}{dt} = \frac{1}{m}\frac{\partial S}{\partial r} - \frac{MG}{r^2}t \tag{10}$$

Where $\frac{S}{\hbar}$ represents the phase of the wave.

Or, from (2) and (8):

$$\frac{dr}{dt} = \frac{rt}{t^2+\tau^2} - \frac{MG}{r^2}t \tag{11}$$

3. Application to the far-away galaxy dynamics

If we consider the motion of a far-away galaxy, taken as "particle", the time parameter τ is very large. For $m \cong 10^{42}$ and $Д$ about the size of our galaxy ($10^{21}m$), τ is around 10^{118}. Consequently, the first term of eq. (11) can be neglected, leading to:

$$\frac{dr}{dt} = -\frac{MG}{r^2}t \tag{12}$$

Let-us consider a homogeneous space with mass density ρ_0:

$$M(r) = \frac{4}{3}\pi\rho_0 r^3 \tag{13}$$

Eq. (12) becomes:

$$\frac{dr}{dt} = -Krt \tag{14}$$

Where
$$K = \frac{4}{3}\pi G\rho_0 \tag{15}$$

And
$$MG = Kr^3 \tag{16}$$

The solution of (14) is a gaussian curve:

$$r = Re^{-K\frac{t^2}{2}} \tag{17}$$

How can this be identified with the present observations of a far-away galaxy motion?

These observations are commonly expressed within the second order parameters:

$$H = \frac{\dot{r}}{r} \tag{18}$$

$$q = \frac{r\ddot{r}}{\dot{r}^2} \tag{19}$$

For the eq (17) dynamics, it is easily found that:

$$H = -Kt \tag{20}$$

$$q = 1 - \frac{1}{Kt^2} \tag{21}$$

Clearly, for the expansion to be positive, our present time t_0 on the curve (17) must be negative, with the present parameters:

$$H_0 = -Kt_0 \tag{22}$$

$$q_0 = 1 - \frac{1}{Kt_0{}^2} \tag{23}$$

H_0 is the Hubble Constant value at the present time. Since q_0 is presently estimated to be equal to ½, it allows to determine our present position on the curve (17):

$$t_0^2 = \frac{2}{K} = \frac{3}{2\pi G\rho_0} \qquad r = r_0 = \frac{R}{e} \tag{24}$$

And finally, from (22) and (24): $H_0^2 = 2K = \frac{4}{t_0^2} = \frac{8\pi G\rho_0}{3}$ (25)

This means that, in fact, **ρ_0 must be the critical density: it is the necessary density to ensure a ½ acceleration parameter.**

Incidentally, our initial proposal to neglect the first term in (11) reveals to be totally valid, since:

$$\frac{\left(\frac{MG}{r^2}\right)}{\left(\frac{r}{\tau^2}\right)} = K\tau^2 = \frac{H_0^2\tau^2}{2} \gg 1 \tag{26}$$

4. An infinitely expanding and contracting dynamics, and the forces in action

What are the forces in action to generate the eq. (17) dynamics? To answer the question, let-us compute the acceleration, from (14) and (16). It can be easily written as:

$$\ddot{r} = -\frac{MG}{r^2} + \frac{\dot{r}^2}{r} \tag{27}$$

where **the second term is nothing else than the radial expansion acceleration (1).**

This important result tends to show that **the expansion force can be considered as a consequence of Quantum Bohmian Mechanics.**

Furthermore, it is notable that the mass repartition (13) of a simple homogeneous universe is the only one to produce the precise extra-acceleration term $\frac{\dot{r}^2}{r}$ in eq (27).

Eq (17) represents the possible trajectory of a galaxy. It describes an infinite evolution in time (no Big-Bang), made of an expansion phase followed by a contraction phase, as illustrated figure 1.

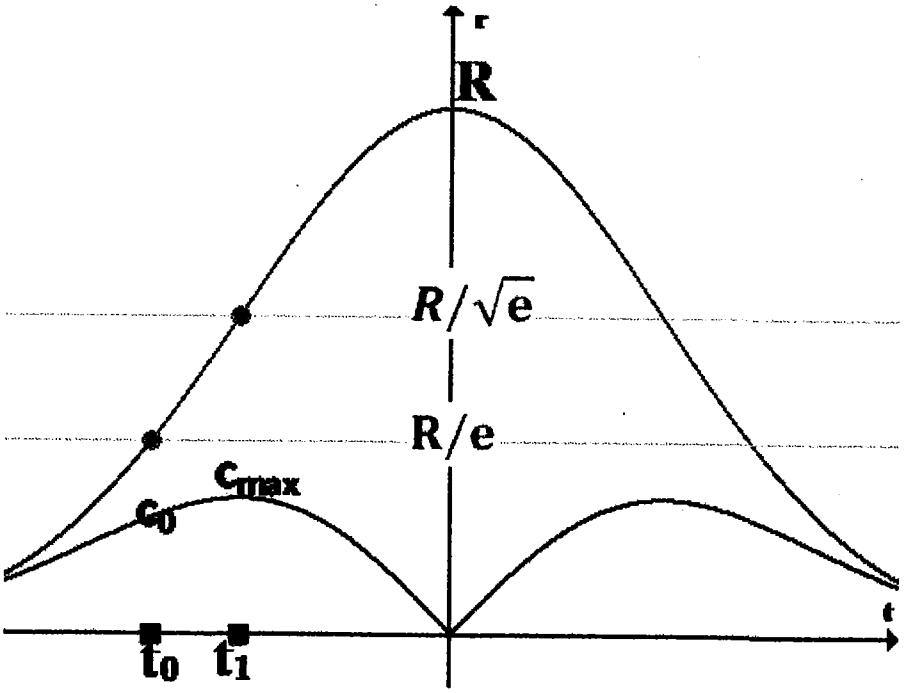

Figure 1. *Eq (17) dynamics for* r *and* $|\dot{r}|$

At the present time ($t_0 < 0, r = r_0 = \frac{R}{e}$), expansion is governed by H_0 and $q_0 = \frac{1}{2}$.

Time t_0 is anterior to time t_1 of the inflection point, where :

$$t_1^2 = \frac{1}{K} \qquad\qquad r = r_1 = \frac{R}{\sqrt{e}} \qquad (28)$$

So, from our present time, expansion will accelerate till time t_1 (< 0), then it will decelerate, up to time 0, from which an infinite contraction period will succeed.

This dynamics is ruled by the two dual forces: the Newtons'force $(-\frac{MG}{r^2})$ and the expansion force $(\frac{\dot{r}^2}{r})$. The first one dominates for $|t| < |t_1|$, and the second above $|t_1|$. Their relative amplitudes vary as:

$$\frac{\left(\frac{\dot{r}^2}{r}\right)}{\left(\frac{MG}{r^2}\right)} = Kt^2 = \begin{cases} \infty & t = \pm\infty \\ 2 & t = t_0 \\ 1 & t = t_1 \\ 0 & t = 0 \end{cases} \tag{29}$$

5. What if Newton's force was alone?

In this case, we should have to solve:

$$\ddot{r} = \frac{MG}{r^2} = -Kr \tag{30}$$

Whose solution:

$$r = r_0\, sin\left(\sqrt{K}t\right) \tag{31}$$

This leads to:

$$H = \sqrt{K} \tag{32}$$

$$q = \frac{-Kr^2}{\dot{r}^2} < 0 \tag{33}$$

Unless to admit that the universe could be made of a uniform negative mass density (which is not the case), $q = \frac{1}{2}$ cannot be obtained. Without expansion force, expansion phases could happen, but they should be decelerated, due to the obvious inward attraction by all other masses. The Universe is not a harmonic oscillator.

This fact tends to validate Bohmian Mechanics on one side, and the expansion force on the other side.

6. Time evolution of H and q

Let-us go back to the eq (17) dynamics.

From (20) to (26), the Hubble and the acceleration parameter depend on t, and their evolutions are given by:

$$\frac{H^2}{H_0^2} = \frac{t^2}{t_0^2} \tag{34}$$

$$q = 1 - \frac{t_0^2}{2t^2} \tag{35}$$

As illustrated figure 1, we see that $|H|$ is proportional to $|t|$. It is well defined at each time and does not depend on the distance of observation at that time. The Hubble Constant (25) is really a constant.

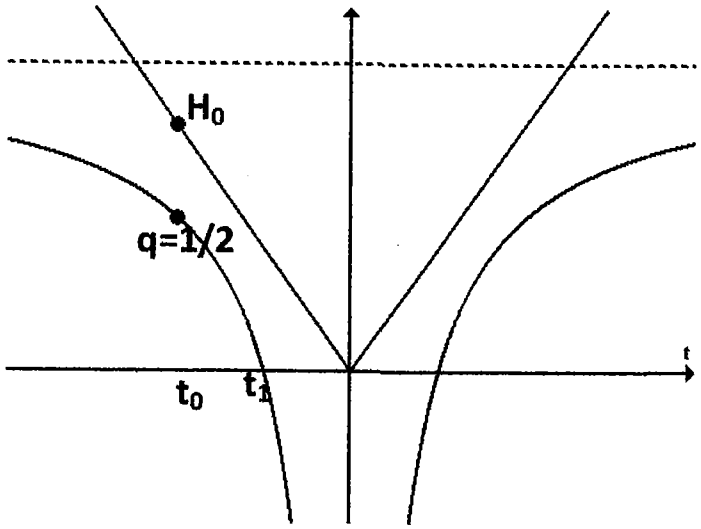

Figure 2. *Temporal evolution of H and q*

The acceleration/deceleration parameter q is symmetrical in t and changes its sign at $\pm t_1$. Its absolute value decreases in the expansion phase and increases in the contraction phase.

As illustrated on figure 1, the dynamics evolution follows four ranges

($t_1 < 0$):

- Accelerated expansion for $t < t_1$
- Decelerated expansion for $t_1 < t < 0$
- Accelerated contraction for $0 < t < -t_1$
- Decelerated contraction for $t > -t_1$

[When t will tend to 0, q will tend to infinity. t=0 is a singular point for our theory, which will have to be improved. It remains a lot of time to do this: 27 Gyears.]

7. Light velocity and radius of the Universe

Let-us recall that a-priori, for a given galaxy, R is a free parameter. Any other galaxy will have another homothetic trajectory with another R parameter. However, it is notable that H and q do depend on t only.

Let-us consider, at a given time, the most remote galaxy among all trajectories with various R coefficients. At this time and for this galaxy, $|\dot{r}| = |H|r = c$ can be assimilated to light velocity. Here, r represents the maximum possible distance in the Universe at that time, due to the maximum possible velocity at that time.

This suggests that light velocity should also vary – according to eq. (17) and (24) – as:

$$c = ec_0 \left|\frac{t}{t_0}\right| e^{-\frac{t^2}{t_0^2}} \tag{36}$$

Where c_0 is the present light velocity:

$$c_0 = H_0 \frac{R}{e} \tag{37}$$

Since c varies as $|\dot{r}|$, it is null for r=0 and $r = R$ and it is maximum for the inflation points where: $c = c_{max} = c_0\sqrt{\frac{e}{2}}$ (38)

It means that light velocity should increase very slowly from now on, and reach its maximum (1,17 c_0) in the time delay:

$$|t_1 - t_0| = \frac{2-\sqrt{2}}{H_0} \sim 8\,\text{Gyears} \tag{39}$$

It means also that light velocity should have been much smaller in the past, for $t < t_0$. As an instance, according to (36) it was a tenth less than its present value around 2,7 Gyears ago.

This "radius" of the Universe will also vary with time according to the gaussian curve and attain its maximum value at t=0: it will be e-times larger than our present Universe radius.

8. Non homogeneous Universe and variation of the Hubble "Constant"

Let-us consider now a more complex Universe made of a non homogeneous mass density such as:

$$\rho = \rho_0 + \rho_1 \frac{r_1}{r} + \rho_2 \frac{r_2^2}{r^2} \tag{40}$$

as an instance of an inhomogeneous model defined by some unknown density parameters ρ_n.

(r_1 not to be confused with eq (28))

The total mass repartition is now the sum of 3 terms, in r^3, r^2 and r respectively, and the Newton's acceleration can be written as:

$$\frac{MG}{r^2} = Kr + \Gamma + \frac{W}{r} \tag{41}$$

with $K = \frac{4\pi G\rho_0}{3}$ $\Gamma = 2\pi G\rho_1 r_1$ $W = 4\pi G\rho_2 r_2^2$ (42)

As above, let-us compute the acceleration from eq (12):

$$\dot{r} = -\left(Kr + \Gamma + \frac{W}{r}\right)t \tag{14 bis}$$

It can be found easily that:

$$\ddot{r} = -\frac{MG}{r^2} + \left[\frac{K-\frac{W}{r^2}}{K+\frac{\Gamma}{r}+\frac{W}{r^2}}\right]\frac{\dot{r}^2}{r} \tag{27 bis}$$

The $\frac{\dot{r}^2}{r}$ term is not exactly found again as in (27), but it tends to it for large radius r. So it can be considered that the same far-away dynamics is again ruled by the same two forces as above.

From (14 bis), the Hubble "Constant" can be derived easily:

$$H_0 = \frac{\dot{r}}{r}(t_0) = -\left(K + \frac{\Gamma}{r_0} + \frac{W}{r_0^2}\right)t \tag{43}$$

It now varies with the distance of observation as:

$$H_0 \sim \frac{M(r_0)G}{r_0^3} = 4\pi G\left(\frac{\rho_0}{3} + \rho_1\frac{r_1}{2r} + \rho_2\frac{r_2^2}{r_0^2}\right) \tag{44}$$

And this depends on the density parameters ρ_n of our model.

I propose to compare this result to all measured values of the Hubble Constant, with different methods [11] [12] [19] [20] [23]. Beyond potential "theoretical biases" in these measurements (whose expressions more or less depend on accepted theories), it may be questioned whether these various employed methods do not consist in **measuring H_0 at different observation distances?** In this case, it may be envisioned that the comparison with (44) makes it possible to calibrate the various results and estimate the corresponding density parameters. This could provide answers to the question of the degree of homogeneity of the Universe and of what kind of real matter it is made of.

In addition, several theoretical attempts have been made to consider potential negative masses [3] [8] [9] [10] [14] [15] [16] [18].It can then be suggested not to exclude negative signs for the density parameters, which will tell us if the presence of negative matter must be considered or not, and under what repartition.

9. Conclusion

I have shown that the observed dynamics of far-away galaxies could be explained by an additional expansion force, which happens to be a consequence of Quantum Bohmian Mechanics.

This proposal tends to build a bridge between Quantum Mechanics and Astrophysics.

The combined action of the two dual forces (Newton's one and expansion force) theoretically produces an infinitely evolving Universe (no Big Bang), with an expansion phase followed by a contraction phase. It agrees with the observations of our time, in particular the fact that the expansion is presently accelerated with a ½ acceleration parameter.

Furthermore, the study of a nonhomogeneous Universe has given us a means to better analyse the present Hubble "Constant" measurements and approach a better understanding of what our Universe is really made of.

A lot of work must be carried out to get a broad understanding of our universe, from the present elementary analysis of this paper, which is in favor of the "fifth force". For a whole universe, full of matter-energy, I have only shown [9] [10] that this force can explain accelerated expansion in a universe having certain symmetry properties. But what is the real situation? So, rigorously, this paper cannot be taken as a validation of expansion of our real universe, neither of the "flat rotation curves" of the galactic stars (serious arguments have been given against this interpretation of the star Doppler shifts [21]). Rigorously for instance, it cannot be excluded that this "fifth force" should be considered as "real" in a nonhomogeneous, nonsymmetrical, not expanding universe, depending on what real material content this universe is filled in.

Only the future experiments and theoretical thinkings will decide, if possible, in what real universe we are, or, more scientifically, what is the most "economically matching" model to represent it.

As far as this process is carried out in an open-minded way, considering what Nature can teach us, instead of being disturbed by what we believe we know.

10. Acknowledgment

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NEW RESEARCH AND DEVELOPMENT OF UNCERTAINTY RELATIONS

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Abstract

Based on the uncertainty principle in quantum theory and the generalized uncertainty principle (GUP), we research uncertain relations of entropy, information and thermodynamics, and propose the speed of light and some fundamental constants should be uncertain. Further, we search its possible development in the entanglement, superstring, and the extensive quantum theory, various matters and different phases, etc. Moreover, the irreversibility and statistics are discussed, and we derive operators of entropy, etc. New measuring technology and some developed theories already challenge the uncertainty principle, which may not be held under certain conditions, and must be modified and developed.

Keywords: uncertainty relation; speed of light; entropy; entanglement; superstring; irreversibility; statistics.

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I. Introduction

It is well-known that quantum mechanics has the uncertainty principle:

$$\Delta x_i \Delta p_i \geq \hbar/2. \qquad (1)$$

This is the limit on the precision to which both its location and frequency measured for a wave. The energy-time uncertainty principle is:

$$\Delta E \Delta t = \hbar. \qquad (2)$$

The Heisenberg uncertainty relation is:

$$(\Delta p)^2 (\Delta x)^2 \geq \frac{1}{4}\hbar^2. \qquad (3)$$

Generally, it points out that for both conjugate quantities (position and momentum, time and energy, etc), one is more precise, and another is more uncertain. This includes position measurement in a microscope, momentum measurement using the Doppler effect, coherence property of light and so on [1]. The general uncertainty principle says that if A and B do not commute, then there is a lower bound on the products of the two variances [2]:

$$< \Delta A^2 >< \Delta B^2 > \geq -\frac{1}{4} < \psi | [A, B] | \psi >^2. \qquad (4)$$

The uncertainty principle is an important base of total quantum theory, and is also a fundamental problem of constant concern. It not only produces a type of uncertain (for example, discontinuous move of particle, and the orbit of particle cannot be described by space-time, etc.), but also derives some relations on quantum theory and relativity, on determinism or statistics, etc.

First, Santilli proposed a unified form of possible generalizations of Heisenberg uncertainty principle for strong interactions [3], which are based on the product of the envelope of the dynamical equations representing wave packets under conditions of mutual overlapping and nonlocal non-Hamiltonian forces. For conventional associative products of operators, he recovered the conventional Heisenberg relations for particles under long range electromagnetic interactions and no appreciable wave overlapping. For nonassociative Lie-admissible products of operators he had (a) a number of generalizations of Heisenberg's equations of increasing algebraic complexity; (b) the capability of representing a correspondingly progressive increase of conditions of wave overlapping and nonlocal, non-Hamiltonian forces; and (c) a corresponding, rather inevitable sequence of generalizations of Heisenberg uncertainty relations. All these possibilities are expressed in a unified way by postulating generalized uncertainty relations whereby the product of operators is that of the envelope of the dynamical equations. For conditions of minimal wave overlapping under strong interactions, such as in the nuclear structure, he expect a very small nonlocal non-Hamiltonian component of the force and a minimal departure from Heisenberg principle. For progressive increase of

wave overlappings, such as in the structure of hadrons, or in the structure of stars undergoing gravitational collapse, he expect a corresponding progressive replacement of Heisenberg principle with more general principles [3]. It is notable that Santilli first proposed the rest of Pauli's exclusion principle (PEP), in particular, for strong interactions, and the structure of hadrons, nuclei and stars [4-6]. Further, Santilli researched inapplicable of PEP in numerous experiments [7].

Pollack discussed uncertain science and uncertain world [8], in which indetermination of archaeology, geology and astronomy represents non-uniqueness. Uffink, et al., shown that actually it is not possible to derive from this relation two central claims of the uncertainty principle. To express the uncertainty principle, one must distinguish two aspects of the spread of a wave function: its extent and its fine structure [9]. It is shown that this relation expresses the uncertainty principle as it is used in the single- and double-slit experiments

Adler, et al., shown the gravitational interaction of the photon and the particle being observed modifies the uncertainty principle with an additional term. From the modified or gravitational uncertainty principle it follows that there is an absolute minimum uncertainty in the position of any particle, of order of the Planck length. A modified uncertainty relation of this form is a standard result of superstring theory, but the derivation is based on simpler and rather general considerations with either Newtonian gravitational theory or general relativity [10]. Yoneya searched the space-time uncertainty principle in string [11]. Busch, et al., demonstrated that the uncertainty principle is shown to appear in three manifestations, which are closely related formally, and they commented on the status of experimental tests of the uncertainty principle [12]. In this paper, we research possible development of the uncertainty principle, and discuss relations with irreversibility and statistics.

2. New Research of Uncertainty Principle

The uncertainty principle implies that one cannot predict the outcomes for both possible choices of measurement to arbitrary precision. If the particle is prepared entangled with a quantum memory, a device which is likely to soon be available, it is possible to predict the outcomes for both measurement choices precisely. Berta, et al., discussed the uncertainty principle to incorporate this case, providing a lower bound on the uncertainties which depends on the amount of entanglement between the particle and the quantum memory, and applied it to witnessing entanglement and to quantum key distribution [13].

Based on the uncertainty principle in quantum theory and its development, we discussed uncertain physics, which includes phase transformation and critical phenomena, condensed matter physics, surface science and material

science, etc. Fluctuation and statistics, and chaos in nonlinear theory all show uncertainty. Further, in chemistry, Earth science, biology, astronomy and social sciences various uncertain phenomena exist widely, so they form general uncertain sciences. This may apply some mathematical methods, in which an important way is fuzzy mathematics, which is related to the multi-value logic and variant logic. Contrarily, uncertain sciences will give an impetus to various developments of uncertain mathematics [14].

Recently, Gour, et al., studied conditional uncertainty principle [15]. Nichol-son, et al., discussed nonequilibrium uncertainty principle from information geometry [16]. Cherian, et al., searched uncertainty principle as a postquantum nonlocality witness for the continuous-variable multimode scenario [17]. In materials science, Wee, et al., searched quantification of uncertainties in thermoelectric properties of materials from this principles prediction method as an approach based on Gaussian process regression [18]. Parks, et al., discussed uncertainty quantification this principles predictions of phonon properties and lattice thermal conductivity [19].

In fact, for general wave wavelength and space cannot be determined at the same time, wavelength must be a certain spatial range; frequency and time cannot be determined at the same time, frequency must be a certain time range. This is already the uncertainty relation of wave.

In 1963 Dirac supposed that an important direction of developing science is study of vacuum. Basic energy ΔE in vacuum is very small, so Δt should be very big.

According to Heisenberg uncertainty principle, small distance q and big momentum p are equivalent, and both are inverse ratio:

$$\Delta p \Delta q = \Delta(Ev/c^2)\Delta q \geq \hbar. \qquad (5)$$

An important direction of particle physics is possibly violations of some basic principles, one of whose key is the uncertainty principle. We proposed a necessary contradiction between the uncertainty principle and the constancy of the speed of light [20]. Based on quantum mechanics we obtained the uncertainty relations of velocity as a ratio of position to time are:

$$\Delta v \Delta(pt) = \hbar, \qquad (6)$$

or

$$\Delta v \Delta(mx) = \hbar. \qquad (7)$$

The speed of light as the velocity is also uncertain, for v=c (6)(7) become:

$$\Delta c \Delta(\frac{\nu}{c^2} x) = 1, \qquad (8)$$

or

$$\Delta c \Delta(\frac{\nu}{c} t) = 1, \qquad (9)$$

where ν is the frequency of light, x and t are position and time of uncertainty, respectively. So long as the uncertainty principle holds, the speed of light

possesses uncertainty necessarily, when x and t and ν are made more definite, c becomes less definite. The speed of light should have the statistical fluctuations inside a small space-time and at high energy. Further, some fundamental constants probably are also uncertain, which correspond to possible change of the fine structure constant [21], and to general inconstant constants [22]. We proposed that relativity and quantum theory will be able to be unified completely only after both are developed [20,14]. Moreover,

$$c\Delta(mv) = \Delta(Ev/c) \approx \hbar c/\Delta q . \qquad (10)$$

For v≈c, $\Delta E \approx \hbar c/\Delta q$. When nucleon collides, $\Delta q \approx 10^{-13}$ cm. For e-p interactions, interacted space is less than the scale of parton (quark) $\Delta q \approx 10^{-14}$ cm, and is $\Delta q \approx 10^{-16}$ cm in experiments of usable weak interaction, so three uncertainty values of energy are:

$$\Delta E \approx 1.97328 \times 10^2 (10^3, 10^5) \text{MeV}. \qquad (11)$$

At high energy and big momentum Δq is very small and ΔE is very big. An experimental result is asymptotically free. The uncertainty principle extends to the multiplicity ΔN, so $[\hat{N}_i, \hat{P}] \neq 0$. Ozawa proposed universally valid reformulation of the Heisenberg uncertainty principle on noise ε and disturbance η in measurement [23]:

$$\varepsilon(Q)\eta(P) + \sqrt{\hbar/2}[\varepsilon(Q) + \eta(P)] \geq \hbar/2 . \qquad (12)$$

Now the quantum entangled state is approved by some experiments [24-26]. In these cases a difficulty is the uncertainty principle, which is probably breaking under some conditions. Because there are weak interaction at 10^{-15} cm and corresponding repulsive force, perhaps hadrons cannot decompose to smaller particle as quark, the rather that superstring.

Now a classical example is that the Which Way (WW) experiments shown a new uncertainty by double-path interferometer and atom interferometer, etc [27-30]. In neutron interferometric double-resonance experiment the delicacy of energy reaches 2.7×10^{-19}eV [27]. Durr, et al., studied origin of quantum mechanical complementarity probed by a which-way experiment in an atom interferometer, in which two ways of space phase ψ_B and ψ_C for two different states |2> and |3> of total angular momentum form quantum entangled state [30]:

$$\psi_T = \psi_B |2> + \psi_C |3> . \qquad (13)$$

It is difficult that determinant electron, neutron, photon pass through which way. This implies the complementarity (the mutually exclusive nature of the wave and particle concepts) [31] and possible breaking of wave-particle duality [32].

These experiments provide some possibilities on developing direction of particle physics. Based on discussion of the statistical foundation of quantum mechanics and total characters of particle physics, we derived a possible direction of theoretical development: new duality of symmetry and statistics [32].

Zhao, et al., researched entanglement detection by violations of noisy uncertainty relations and a proof of principle [33].

Usual physics is very exact. But, its complexity increases along physical development, and the complexity produces necessarily uncertain. The complexity is excluded with exactitude.

Light is classified by Gamma ray, X-ray, ultra-violet ray, infrared ray, short wave radio, long wave radio and visible light which classifies seven colors. Simultaneously, light is wave, and is also photon. The duality of light and particle is complementary, and shows some uncertain.

In phase transformation and critical phenomena, three usual phase transitions of solid-liquid-gas are three types of two phase coexistence [34,35]. Under the critical point a change between liquid and gas is continuous, and both cannot be distinguished. They form some uncertain regions, in which the degree of membership for both phases is different along change of character.

Moreover, matter form the supersaturated state, the supercooled state and other new states at exceed phase transition point, they are indeterminate and uncertain. In various critical phenomena both and few different phases coexist for some critical points and critical regions (the second type, the n-th type). The degeneration of higher dimensional phase space produces uncertain. The mecroscopic systems and nano-physics (1~100nm) all have the transition region and uncertain.

Condensed states include solid and liquid, in which many transition states exist, for example, classical crystal, multi-crystal metal, non-crystal metal, non-crystal, liquid crystal and liquid, etc. Moreover, there are soft matter and cluster, etc. In these states some uncertain exist. Some properties of matter have the uncertain transition regions, for example, conductor and nonconductor on electricity or heat, elasticity and plasticity, hardness and softness, metal and non-metal, acidity and basicity, and luster, transparency, etc.

In new surface science and material science many transitions regions and properties exist widely. First, any ideal absolute pure states do not exist in nature. Next, material can be constructed from various matters and their mixtures by different ratios. Third, at present many properties in surface science and material science are determined by experiments. Therefore, uncertain mathematics should be able to be applied.

Theoretical physics is usually classified by mechanics, thermodynamics and statistics, electrodynamics and quantum mechanics. In these regions uncertainty exists.

3. Generalized Uncertainty Principle

Recent, the generalized uncertainty principle (GUP) becomes a focus in quantum theory [36-79]. Silvert first discussed set of generalized uncertainty relations and the nature of the uncertainty principle [36]. Roy and Singh searched generalized coherent states and the uncertainty principle [37]. Maggiore studied quantum groups, gravity, and the generalized uncertainty principle [38].

Kempf, et al., proposed first a modified commutation relation of GUP between position and momentum, that for one-dimensional systems [39,40]:

$$[q,p]=i\hbar[1+\beta p^2], \qquad (14)$$

where β is a parameter that describes the scale at which quantum-gravitational effects become relevant.

Adler, et al., discussed gravity and the uncertainty principle [41]. Bambi, et al., searched a gedanken experiment for the simultaneous measurement of position and momentum of a particle in de Sitter spacetime, and proposed a further extension of GUP which suggests the existence of a minimum observable momentum [42]. The new GUP is directly connected to the non-zero cosmological constant, which becomes a necessary ingredient for a more complete picture of the quantum spacetime. Khodadi researched space tests of GUP [43].

Setare analyzed the corrections to the Cardy-Verlinde formula from GUP [44]. Medved, et al., discussed GUP and the Bekenstein-Hawking entropy when conceptual worlds collide [45]. Kim, et al., studied entropy of the Randall-Sundrum brane world with GUP [46]. Bang, et al., proposed quantum mechanics and GUP [47].

Battisti, et al., researched quantum dynamics of the Taub universe in a GUP framework [48]. Vakili discussed dilaton cosmology and noncommutativity for GUP [49]. Liu, et al., studied quantum statistical entropy and minimal length of 5D Ricci-flat black string with GUP [50]. Li discussed energy distribution of massless particles on black hole backgrounds with GUP [51]. Bina, et al., studied quantum black hole in GUP framework [52]. Kober, searched gauge theories under incorporation of GUP [53]. Eune, et al., researched Lifshitz scalar, brick wall method and GUP in Hořava-Lifshitz gravity [54]. Said, et al., studied GUP in f(R) gravity for a charged black hole [55].

Pedram proposed new approach to nonperturbative quantum mechanics with minimal measurable length uncertainty for quantum gravity such as string

theory, loop quantum gravity, and black-hole physics, and the Heisenberg uncertainty principle is changed to the Generalized (Gravitational) Uncertainty Principle (GUP) [56]. Frassino, et al., discussed Casimir effect in minimal length theories based on GUP [57]. Das, et al., studied path integral for nonrelativistic GUP corrected Hamiltonian [58]. Bojowald, et al., searched GUP and localization of a particle in discrete space [59]. Benzair, et al., calculated the propagator for Dirac oscillator in (1+1) dimension with deformed commutation relation of the uncertainty principle by path integral [60].

Husain, et al., studied GUP and quantum field theory [61]. Sailer, et al., derived some consequences of GUP induced ultraviolet wave-vector cutoff in one-dimensional quantum mechanics [62]. Lidsey discussed the holographic cosmology from the first law of thermodynamics and GUP [63]. Pramanik searched implication of the geodesic equation in GUP [64]. Pedram searched GUP and the conformally coupled scalar field quantum cosmology [65]. Hammad studied f(R)-modified gravity, Wald entropy and GUP [66]. Gao, et al., studied to constrain GUP with cold atoms and with the atomic weak-equivalence-principle test [67,68].

Alonso-Serrano, et al., studied GUP impact onto the black holes information flux and the sparsity of Hawking radiation [69]. Lambiase, et al., discussed Lorentz violation and GUP [70]. Maluf, et al., searched thermodynamics of a class of regular black holes with GUP [71]. Ong, et al., researched GUP and white dwarfs, and the cosmological constant protects the Chandrasekhar limit [72]. Gangopadhyay, et al., carried out path-integral formulation to compute a particle with GUP and correspondence with noncommutativity [73]. Bushev, et al., discussed tests of GUP with macroscopic mechanical oscillators and pendulums [74]. Skara, et al., studied primordial power spectra of cosmological fluctuations with GUP and maximum length quantum mechanics [75].

Park, et al., discussed GUP and point interaction and d-dimensional quantum mechanics [76,77]. Iorio, et al., studied GUP in three-dimensional gravity and the BTZ black hole [78]. Budiyono, et al., researched nonlinear Schrödinger equations and GUP from estimation schemes violating the principle of estimation independence [79].

4. Development of Uncertainty Principle

A possible unification of two mutually incompatible fundamental theories (Quantum Mechanics and General Relativity) is Quantum Gravity (QG), whose Quantum Gravity Phenomenology (QGP) studies QG effects in low-energy systems. The basis of one such phenomenological model is the Generalized Uncertainty Principle (GUP), which is a modified Heisenberg uncertainty relation and predicts a deformed canonical commutator. Bosso computed Planck-scale corrections to angular momentum eigenvalues, the hydrogen

atom spectrum, the Stern-Gerlach experiment, and the Clebsch-Gordan coefficients, and analyze the GUP-perturbed harmonic oscillator and study new coherent and squeezed states. Furthermore, he introduced a scheme for increasing the sensitivity of optomechanical experiments for testing QG effects, and suggested future projects that may potentially test QG effects in the laboratory [80].

Generally, a particle in motion has velocity v and momentum p, its position is uncertain; conversely, x is determined, it does not move. Especially, so is wave. This seems to be related to the Brownian movement. Uncertainty is probably based on no-interaction or some particular waves, such as linear waves. If the premise changes, such as nonlinear waves, solitary waves and so on, the uncertainty is probably different. Based on this, it can be deduced concretely.

So far, some increasing experiments seem to challenge the uncertainty principle. Based on the uncertainty relation $\Delta E\Delta t = \hbar$, it becomes $\Gamma = 1/\tau$, i.e., the width of resonances. For strong decay resonance $\Delta t \sim 10^{-23} s$, so $\Delta E = h/\Delta t \sim 65.8 MeV$ is an uncertain energy. We may measure respectively ΔE and Δt of the same resonance or particle to test the uncertainty relations. Now mass of some particles (p, n, e and so on) and Lamb shift are all very precise. Are there any contradictions with uncertainty? From $\Delta E\Delta t = \hbar$ it may determine Δt. Moreover, we should study the uncertainty relation in WW experiments.

The uncertainty relation exists between conjugate quantities, which are non-commutation. According to the uncertainty principle, the measurement accuracy of quantity A is improved continuously, the measurement accuracy of its conjugate quantity B will be continuously decreased. What are conjugate quantities of anomalous magnetic moment and Lamb shift, which form the uncertainty relation?

Quantum entanglements and long distance teleportation have been proved by experiments, and the difficulty lies in the uncertainty principle. Since uncertainty principle and quantum no-cloning theorem, entanglement and complete quantum teleportation are restricted. But the principle may also be broken down under certain conditions. Determination of two entangled states is not only superluminal, and it is not uncertainty, and can be determined without measurement. But, usual entangled state is difficult to last for a long time and a long distance.

Assume that the entangled equation is:

$$(\nabla^2 - m^2)\varphi = G, \tag{15}$$

$$\varphi = -Ge^{-mr}/r. \tag{16}$$

The entangled states have interactions. Newton's gravitation is action at a distance, which may enlighten the description of quantum entanglement. If there is an entangledon (particle of entanglements), it should be detectable.

According to the uncertainty principle $\Delta E\Delta t = \hbar$, $mc^2(l/c) = \hbar$, so

$$mc^2 = c\hbar/l = 3\times10^{10}(cm/s)\times 6.6\times10^{-22} Mevs/r. \quad (17)$$

When r=1m~1000km, $mc^2 = 1.98\times10^{-7} eV \sim 1.98\times10^{-13} eV$. This is smaller than neutrino, so it is easier to run through. The interaction strength G and g can be large or small. But, its velocity will be far bigger speed of light c, and mass increase. In a word, quantum entanglement great challenges to quantum mechanics, which include uncertainty principle and so on. They may no longer hold, or must be developed. If there is no entangledon, it will become a new kind of field and interaction, which is not one of the exchange particles. First, we should determine that its mathematical field is scalar, vector, tensor, spinor, torsion, or other.

The atomic laser trap (diameter 10 μm) at very low temperature ($1\mu K = 10^{-6} K$) proposed by Steven Chu, et al. The transition frequency accuracy of hydrogen from 1s to 2s can achieve 3×10^{-12}. Δt~10^{-15} s, so $\Delta E = \hbar/\Delta t \sim 6.58\times10^{-7} MeV$. Laser time accuracy of cold atoms can achieve $10^{-16} \sim 10^{-18}$ s. By the optical tweezers, atomic force microscope, magnetic tweezers and so on, individual atom may directly be detected. Today new measuring technology may observe specific positions and orbits and spin of individual electrons, which involves measuring time and space. These test directly the uncertainty principle. All in all, it seems that more and more experiments challenge uncertainty principle. At a minimum, these new developments offer the possibility of the experimental tests of uncertainty relations.

Quantum mechanics thought that the particle motion has no orbit, but which seems to be modified in theory the Feynman diagrams and the experimental trajectory of particles, and the optical tweezers, etc.

We may combine uncertainty and chaos derived from the nonlinear theory, since both are all not identified. We consider that uncertainty relation $\Delta E\Delta t \geq h$ and conservation laws are inconsistent. If Δt is the time interval required to measure energy or energy changes ΔE, so the photon is stable $\Delta t \rightarrow \infty$ and $\Delta E \rightarrow 0$, and the speed of light is constant. But, then the moving speeds of all stable particles should be invariant. Such the conservation laws are possibly uncertainty and statistical.

We propose that the uncertainty relations must possibly be modified or developed. 1). The smaller the space, the bigger the energy. It is extended to particle structure, in which the smaller the particle, the more definite the space,

the bigger the uncertainty value of energy, and the bigger the mass. In the limit case, the particle is infinitely small, the mass will be infinite. Conversely, if the particle mass has an upper limit, it will have a certain limit corresponding to the segmentation of particles is not infinitely separable. Or the Heisenberg uncertainty principle itself is no longer valid under certain conditions. 2). At this time, the larger the fluctuation, the phase transition should occur when a certain threshold is reached. 3). When wave and particle develop into solitary wave, soliton and other nonlinear theories, the uncertainty relations of wave and quantum should be developed. If the area (probability, energy, etc.) of Λ-type soliton is conserved, the larger the space (width), the shorter the height; the smaller the space, the higher the height. According to the nonlinear quantum theory of quantum mechanics, we proposed the basic nonlinear operators $p_\mu = -i\hbar(F\frac{\partial}{\partial x_\mu} + i\Gamma_\mu)$, from this the uncertain commuting relations) are [25,78]:

$$x_\mu p_\nu - p_\nu x_\mu = i\hbar F\delta_{\mu\nu} - i\hbar(x_\mu F - Fx_\mu)\frac{\partial}{\partial x_\nu} + \hbar(x_\mu\Gamma_\nu - \Gamma_\nu x_\mu). \quad (18)$$

4). Supersymmetry, super-Lie algebra is commutation or anti-commutation relations, this should be developed. 5). It may be similar to Brownian motion, which is a result of interactions between the particles and vacuum. So the uncertainty should agree with the statistical distribution, such as MB or FD or BE distribution. The development direction may be mainly related to high energy, small space-time. The key is the relations with the experiment. Increasing experiments seem to challenge the uncertainty principle, whose experiments may test a series of new development.

K. Popper pointed out that the uncertainty relation can be derived from the basic principles of quantum mechanics, so it is not an independent principle [74]. Margenau pointed out, the uncertainty relation should only be understood in the statistical meaning of multiple measurements [75]. For the uncertainty relation between time and energy, the argument is greater. In 1933 Pauli pointed already out, it was impossible to introduce a time operator, so there is not commutation relation between energy and time [76].

The uncertainty relation of wave $\Delta x\Delta k = 1$ shows uncertainty between packet length and wavelength. This is the nature of wave, which is independent of quantum theory. At the same time, wave of particle and its equations lead to discrete states of energy (i.e. quantization). Bohm pointed out that uncertainty principle is derived from three basic hypotheses: wave-particle duality, probability, inseparability of energy-momentum, and three combinations [77]. Their unity is the foundation of the whole quantum theory.

The uncertainty relation in atoms is $\Delta E_n \Delta t = \hbar$. i.e.,

$$\Delta(-2\pi\hbar R\frac{Z^2}{n^2})\Delta t = h, \tag{19}$$

so $$\Delta t\Delta(\frac{1}{n^2}) = \frac{1}{RZ^2}. \tag{20}$$

Usual n and t are uncertainty. Generally, it is:

$$\Delta(R\frac{Z^2}{n^2})\Delta t = 1. \tag{21}$$

Here R is Rydberg constant. For atom with fixed Z and n, as the hydrogen atom with Z=1 and n=1 can only be $\Delta t \to \infty$, or $\triangle$R is not equal to 0, it is uncertainty. Or ΔE_n is uncertainty, and the formula does not hold. That is relation between $\triangle$t and the Ritz combination rule:

$$\nu = R(\frac{1}{m^2} - \frac{1}{n^2}). \tag{22}$$

It is namely:

$$\Delta\nu\Delta t = 1. \tag{23}$$

Such $\Delta\nu \to 0$, then $\Delta t \to \infty$. This must admit that it can not be described by time and space. At present, the spectrum is quite accurate, big n is easier to test accurately.

If the current form of wave is different, the uncertainty principle will be developed, for example, nonlinear quantum theory [32,85]. Further, the uncertainty relation may be extended to one of various uncertainty quantities $\Delta p_i, \Delta x_i$ (Δp, ΔE ; Δx, Δt). Δp corresponds to $\Delta E = (\Delta p)^2/2m$, since $\Delta E\Delta t \geq h$, so

$$(\Delta p)^2 \Delta t \geq 2mh. \tag{24}$$

Conversely, $\Delta p \geq h/\Delta x$, so $\Delta E = (\Delta p)^2/2m \geq h^2/2m(\Delta x)^2$,

$$\Delta E(\Delta x)^2 \geq h^2/2m. \tag{25}$$

$(\Delta p\Delta x)^2 \geq h^2$ is divided by Eq.(24), and obtain

$$(\Delta x)^2/\Delta t \geq h/2m, \text{ or } \Delta x\Delta v \geq h/2m. \tag{26}$$

This is consistent with our uncertainty formula for the speed of light [20,14].

The field equation and its soliton solution can describe the orbit of particles in principle. This may be related to de Broglie-Bohm nonlinear wave mechanics [86]. Such the relation between soliton and uncertainty is inconsistent. More generally, it is the relation between nonlinear quantum theory [32,85] and uncertainty principle.

Two quantities of operator each other constitute the conjugate quantity. Two noncommutation operators cannot be measured at the same time, which

are the most universal uncertainty relations. We discuss its general mathematical form, let [M,N]=MN+NM=iG, and assume G is uncertainty scale. Its special example is an anticommutation relation for G=0. Both representations of operator each other are:

$$M = iG\frac{\partial}{\partial N} \text{(in N representation).} \qquad (27)$$

Conversely,

$$N = -iG\frac{\partial}{\partial M} \text{ (in M representation).} \qquad (28)$$

Such $\Delta M \Delta N \geq G.$ (29)

5. Quantum Theory, Irreversibility and Statistics

Prigogine, et al., considered that a basic difficulty of quantum theory is the inability to describe irreversible processes. It should combine generalized entropy (information) and introduce microscopic entropy, quantum entropy, etc. Quantum mechanics is statistical, and statistics can describe irreversibility, so quantum mechanics should describe irreversibility. The equation of quantum mechanics is similar to the statistical equation of molecular motion theory, so it possesses statistics. Classical and quantum values are arbitrary and discrete values.

Brownian motion, ground state energy h/2, absolute zero can not reach, all indicate the existence of permanent motion in the microscopic field. Under certain conditions Brownian motion may be amplified to macroscopic Brownian motion effect, although energy has possibly been input in this amplification.

According to the definition of entropy

dS=dE/T, (30)

entropy introduced needs inevitably temperature T. According to

$$S = -k\lg P = -2k\lg\psi, \qquad (31)$$

ψ change derives S change. Increase entropy corresponds to the wave packet must spread. It is obtained from Eq.(31):

$$dS = -2k\frac{d\psi}{\psi} = -2k\frac{1}{\psi}\left(\frac{\partial\psi}{\partial x_1}dx_1 + \frac{\partial\psi}{\partial x_2}dx_2 + \frac{\partial\psi}{\partial x_3}dx_3 + \frac{\partial\psi}{\partial t}dt\right), \qquad (32)$$

$$dS = -2k\frac{1}{i\hbar}(p_x dx + p_y dy + p_z dz - Edt) = 2i\frac{k}{\hbar}p_\mu dx_\mu, \qquad (33)$$

k/$\hbar$ is the combination constant. It is similar to $\psi = A\exp(ip_\mu x_\mu/\hbar)$. This is namely dS corresponds to four vector momentum.

For stable state

$$i\hbar\frac{d\psi}{dt}=E\psi, \tag{34}$$

so $$dS=-2k\frac{E}{i\hbar}dt. \tag{35}$$

S and t are all reversible or irreversible, and both changes are proportional. The entropy of the isolated system increases and the conservation of energy is a stable state, so time is also direction.

When we consider the time arrow and statistics, energy develops to entropy. Prigogine introduced the microscopic entropy operators, this can be combined with the introduced method of temperature and entropy in particle physics. His hyperoperator leads to irreversibility. This may correspond to nonlinear operators. More generally, the renormalizable quantum theory should combine semigroups [87], and introduce temperature, etc., then irreversibility is derived.

Assume that entropy and a quantity Y are conjugate, $\Delta S=\Delta E/T$, $\Delta E\Delta t=(\Delta S)(T\Delta t)$, so Y=Tt for invariant T.

$$\frac{dF}{dY}=\frac{dF}{Tdt}=[F,S]=\frac{[F,H]}{T}. \tag{36}$$

From this operator of entropy is:

$$S=\frac{i\hbar}{T}\frac{\partial}{\partial t}, \tag{37}$$

Assume that the conjugate quantity of momentum flux density $T_{\mu\nu}=mc^2v_\mu v_\nu$ is X. If $T_{\mu\nu}=-i\hbar\frac{\partial}{\partial X}$, so

$$\Delta T_{\mu\nu}\Delta X\geq\hbar,\ T_{\mu\nu}X-XT_{\mu\nu}=i\hbar. \tag{38}$$

It combines the uncertainty relation:

$$p_\mu v_\nu X-Xp_\mu v_\nu=p_\mu x_\mu-x_\mu p_\mu=i\hbar, \tag{39}$$

so $$X=x_\mu/v_\nu,\ \ T_{\mu\nu}=-i\hbar\frac{\partial}{\partial(x_\mu/v_\nu)}. \tag{40}$$

Here v_ν is operator $-i\hbar\frac{1}{m}\frac{\partial}{\partial x_\nu}$.

Quantum mechanics and statistical mechanics are all based on the average values, and both should be developed by analogy. The equation of density ρ is Liouville equation, which corresponds to Heisenberg equation, but is not Schrodinger equation. Quantum mechanics may be developed to quantum statistics by similar statistical mechanics. By similar quantum

mechanics statistical mechanics is developed to dynamics and equations. In particular, quantum statistics should include the Thomas-Fermi equation.

Quantum mechanics, quantum field theory, and statistics all hold for multiple particle events. We should organize, express and modify quantum mechanics and quantum field theory using the statistical way, and then extend and develop quantum theory.

Quantum mechanics of path integrals can be interpreted as implied fluctuation around classical trajectories [88]. This is a unified schema of quantum mechanics, field theory, and statistical models. If the trajectory represents photon (corresponding to Fermat's shortest path principle, etc.), quantum mechanics will be fluctuation. The commutation relation of quantum mechanics $pq - qp = ih$ derives the uncertainty relation $\Delta p \Delta q \approx h$. Various commutation relations of quantum field theory should derive various uncertainty relations. Any kind of wave has is representation of similar uncertainty relations, which is one of the basic conclusions of the Fourier analysis of the wave process. Uncertainty is a universal relation of wave [89].

The known size of superstring is very small $\Delta x \cong 10^{-35} cm$. According to the uncertainty principle, a corresponding momentum of superstring is:

$$\Delta p = h / \Delta x \cong 6.626 \times 10^{8} gcm / s . \qquad (41)$$

If the velocity of superstring is approximately velocity of light, its moving-mass will possess a macroscopic mass $5.618 \times 10^{26} MeV / c^2 = 2.209 \times 10^{-2} g$ [20,14]. 1999 and 2004 Nobel Prize Laureates in Physics M. Veltman and F. Wilczek, et al., proposed some different viewpoints for superstring [90,91].

Polzik, et al., proposed the method for entanglement of two quantum states [92]. Further, it will be that hundreds of millions of atoms entangled. Quantum entanglement of macroscopic objects contain entangled spin of Cs gas about 10^{12} atoms for 0.5ms. If it is fermion, it will violate PEP [93-98], and short time corresponds to high energy; if it is boson, it will correspond to BEC at high temperature. This can be related to macromolecular formation, atomic groups, chemistry, biological composition, etc., until the unity of man and nature. In short, we need to be studied in depth many basic problems in particle physics.

The free energy is associated with the occurrence of two conjugate variables *a* and *b* (such as entropy and temperature, volume and pressure, chemical potential and particle number, magnetic moment and external field, etc.), and both form a relation:

$$a = \frac{\partial w}{\partial b}. \qquad (42)$$

Absolute zero T_0 is a limit of temperature, which is similar to invariant speed of light, and c, h, etc., are all constant. T_0 connects to basic energy E_0=cT_0 should be also uncertainty. It corresponds to the zero point energy hv/2 (which is inseparable, and is half a quantum), which is uncertainty, such as Δ(hv/2)Δt=h. This corresponds also to S_0,

$$S = \int_0^T (C_X / T) dT . \qquad (43)$$

Such entropy S is also uncertainty. Here C_X is heat capacity. $dQ = C_X dT$, $\Delta Q \Delta t$=h derive

$$\Delta T \Delta t = h / C_X , \ \Delta S \Delta t = C_X (\Delta T / T) \Delta t = h / T \text{ or=h/}\Delta\text{T.} \quad (44)$$

Entropy and information like energy should have the uncertainty relations. $\Delta S >> h/tT$ [27], it may have other forms.

The heat information-entropy uncertainty relation is [99]:

$$U[X, P : \psi, \overline{\psi}; \beta] \geq 1 + \ln \pi + \ln\{\cosh[2\vartheta(\beta)]\} . \qquad (45)$$

This may obtain the heat Heisenberg uncertainty relation:

$$\Delta x \Delta p \geq \frac{1}{2} \cosh[2\vartheta(\beta)] . \qquad (46)$$

This is easily extended to light and its thermal fluctuations and so on.

Entropy also has uncertainty relation. S=klnW, so probability is also uncertainty. This corresponds to the uncertainty of the predicted results by futurology or Yi, etc. According to the uncertainty relation of information, any information has all uncertainty. The uncertainty relation is not only limited to quantum theory and waves, but also corresponds to the extended quantum theory [100-102], which can be used in astronomy, chemistry, etc.

The uncertainty relation of quantum thermodynamics is $\Delta x \Delta p \geq h$, so temperature is lower, the superfluidity appears, the smaller the speed, Δp is more certain and Δx is more uncertain, i.e., when Δp is extremely small, Δx is very big. This may have to be modified, otherwise for absolute zero v=0, and p=0, x will be completely uncertain. At the same time, the particle wave and uncertainty relations are particularly strong at low temperature and low speed. This and relations of superconductivity and superfluidity are worthy of further study.

Temperature measured by units of energy is Θ=kT. Θ=kT is similar to E=hv, $E = mc^2$, so k corresponds to h and $1/c^2$. Blackbody radiation formula is regardless of frequency v high, low or arbitrary value, as long as k→0 it will be E→0. If k=0, the Boltzmann factor $\exp(-E/kT) = 0$.

Energy is quantized, then entropy, temperature and other thermodynamic quantities should also be quantized. Low temperature corresponds to superconductivity, probably high temperature corresponds to supersymmetry.

Recently, based on the non-commutation $[A,B]=AB-BA=\eta\neq 0$ of matrix, group, tensor and so on, we proposed the mathematical quantum theory. If η is imaginary number, it will correspond to the extensive quantum theory. If η is real number, it will be development of quantum theory. Moreover, η may be complex number, etc. We introduced a similar wave function and corresponding operators, various similar quantum results will be derived. Further, we discussed its physical meaning and various applications. Based the general matrix we researched mathematics of unified gravitational and electromagnetic fields, and discussed the space-time equations and the simplest unifying quantum theory and general relativity [103]. Usual quantum-matrix mechanics has non-commutation, which is related to operator of mechanical quantities and uncertainty relation.

We proposed a new developed pattern of number system: The quaternion is extended to a matrix form *aI+bC+cB+dA*. They form usually a ring. But some fields may be composed of some special 2-rank, even n-rank matrices [104]. It seems to correspond to certainty in quantum mechanics. Further development is general nonlinear algebra.

If the non-conjugate quantities form a set of base, which corresponds to an equal-order diagonal matrix, such as vector, it will be possible for the accuracy measurement. They may be commutation.

Matrix is related to Dirac equations, here β,α_i are anti-commutation. If I and σ_i are commutation, space-time and momentum-energy will able to exist simultaneously [103], and be determined. KG equation is not matrix, is there the uncertainty relation?

Heisenberg equation is:

$$\frac{dF}{dt}=\frac{1}{ih}[F,H]=\frac{1}{ih}(FH-HF). \qquad (47)$$

F and H can be commutation. If dF/dt=0, F is conservation. F and H are non-commutation, F is uncertainty.

So far the high energy experiments in the past sixty years shown that the smallest mass fermions are proton, electron, neutrino and photon, which form the simplest model of particles. These fermions seem to be inseparable truth "atoms" (elements), because further experiments derive particles with bigger mass. They correspond to four interactions, and are also only stable particles. Next, the final simplest theory is based on leptons (e-ν_e) and nucleons (p-n) or (u-d) in quark model with SU(2) symmetry and corresponding Yang-Mills

field. Other particles and quark-lepton are their excited states. Their spectrum is mass formula and symmetric lifetime formula. Some applications are discussed. Further, the simplest interactions and simplified QCD are discussed. We research opposite continuous separable models. Finally, we propose some possibly developed directions of particle physics, for example, violation of basic principles, in particular, the uncertainty principle, and precision and systematization of the simplest model, etc.

Mass of quark model is uncertainty, for example, m(u)=1.5-3.0MeV and m(d)=3-7MeV, etc.

6. Discussions

Generally, if the uncertainty principle holds always, it will exclude any points from various point particles and point charges to origins of space-time in Big Bang and general singularity in Universe. For Big Bang Eq.(2) holds, so the larger is t and E the smaller, which is the qualitative consistency, but the specific calculation Planck time t=$10^{-43}s$ corresponds to:

$$\Delta E = \hbar/\Delta t \cong 6.58\times10^{-22} MeVs/10^{-43}s = 6.58\times10^{21} MeV \text{ . (48)}$$

In particular, t=1s, so E=$6.58\times10^{-22} MeV$ is completely inconsistent with the known nuclear synthesis E~1MeV in Big Bang.

Now there are some generalized uncertainty relations, which may be Eq.(14) or (44), etc. We may research some possible developments of uncertainty relation:

1. General wave has all it. This is related to the mechanical wave theory [105].

2. For superstring, entangled states, various matters and different phases, some constants, etc., it must possibly be developed.

3. In the extensive quantum theory [100-102] h→H is bigger or smaller. Based on $\hbar c/e^2 \approx 137$, here c is related to relativity and space-time, e is related to charge and electromagnetic field, $\hbar$ is related to quantum theory, Dirac supposed that $\hbar$ is not a basic constant, so that the uncertainty theory will be developed. If $\hbar$→H, it will also form the extensive quantum theory.

4. For accurate mass and lifetime, what impacts it?

5. Probably, the precision of anomalous magnetic moment and Lamb shift will modify it.

In a word, new measuring technology and some developed theories already challenge the uncertainty principle. It may not be held under certain conditions, and must be modified and developed. This is included in various unified theories [106].

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THE RELATIONSHIP OF DENSITY WITH THE SIZES OF ATOMS AND THEIR NUCLEI

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Abstract

The analysis of the relationship between the density of elements (metals and semimetals) with the parameters of atoms and their nuclei is carried out. It is shown that there is a weak correlation between the density and the diameter of the atom. The relationship between the density and diameter of the atomic nucleus is more significant. A high correlation has been revealed between the density and the ratio of the nuclear volume to the atomic volume.

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Density is one of the most important parameters of a substance. It is known that the density of an element, as a whole, increases as its number increases in the Periodic table. For metals, this trend is even more pronounced. At the same time, it is unclear how the density value depends on the parameters of atoms and their nuclei. One of the factors influencing the density is the size of the atom, determined by the diameter of the orbits of the outermost, most distant electrons from the nucleus. Another factor is that the bulk of the atom of an element is concentrated in its nucleus. The masses of the elements nuclei increase in proportion to the atomic number of the element. At the same time, the strict dependence of the density of a substance on the atomic number and its atomic weight (mass) is not observed. Probably, this dependence is influenced by the ratio of the atom sizes of the elements. To analyze this effect, a summary of the parameters of a large group of elements (metals and semimetals) has been compiled, including the name of the element, its formula, atomic number, atomic weight (A), density (ρ), atom diameter (Da) and nucleus diameter (Dn), (Table).

As is known, atomic weight is the weighted average partial atomic mass of all natural stable and unstable isotopes contained in a given chemical element. In the Table, the atomic weight values are given from [1]. The density of chemical elements has been repeatedly measured and is given in a large number of publications [2, 3].

In many cases, the shape of an atom can be approximated by a sphere [4]. The size of the radius (diameter) of an atom depends to a certain extent on whether the atom is isolated, covalently bound in molecules in a condensed medium, or in ionized and excited states. The diameter value varies both from the state of the atom and from the environment. The values (Da) presented in the table refer to isolated, free atoms. They are taken from [4] where they are calculated by the Hartree-Fock calculation method. According to the author of the work, the Hartree-Fock method is currently the most effective of the available methods for calculating the size of the electron shells of atoms.

The sizes of atomic nuclei are primarily related to the action radius of nuclear forces. Different methods give different sizes of atomic nuclei. In the work specially devoted to the theory of the atomic nucleus, methods are listed by which the sizes of the atomic nucleus are determined [5]. For example, according to the method for determining the section of nuclear reactions, the radius of the nucleus is

$$R_n = a_0 \sqrt[3]{A} \cdot 10^{-15}\ m, \qquad (1)$$

where $a_0 = 1.4$.

By the method of measuring the electrostatic interaction of protons in the nucleus, it was found that $a_0 = 1.5$. The scattering of electrons by atomic nuclei made it possible to estimate the coefficient $a_0 = 1.2$. Using the energy of X-ray radiation of μ-mesons, it was found that $a_0 = 1.2$. The approach that allows representing the nucleus as a uniformly charged Coulomb sphere gave the value $a_0 = 1.23$.

A detailed analysis of different methods for calculating the radii of nuclei is given in [6]. For heavy nuclei, slightly different results were obtained by different methods. They all lie within the limits

$$R_n = (1.2 - 1.5)\sqrt[3]{A} \cdot 10^{-15}\ m. \quad (2)$$

Similar results are given in [7]. Summarizing the above results, we can obtain the average $a_0 = 1.3$. Thus, the average atomic nuclei diameter

$$D_n = 2.6\sqrt[3]{A} \cdot 10^{-15}\ m. \quad (3)$$

According to the data in the Table, the density of the group of substances varies from 0.53 g/cm^3 (lithium) to 22.6 g/cm^3 (osmium, iridium). The atomic size range is $2.44 \cdot 10^{-10}$ m (germanium) – $5.34 \cdot 10^{-10}$ m (cesium). Changes in core diameters are in the range of $4.96 \cdot 10^{-15}$ m (lithium) - $15.43 \cdot 10^{-15}$ m (bismuthum, polonium).

It is known that an atomic mass is concentrated in its nucleus [5-7]. The ratio of the nucleus mass to the sum of the electron masses of the atom is approximately 2000/1. In addition to the mass of atomic nuclei, the density of a substance depends on the distance between its atoms (molecules). This distance is determined by the size of the electron shells of the atoms. The Table shows that alkali metals have the largest sizes of electron shells at a relatively low density.

The plot, Fig. 1, shows the field of points ρ vs Da. From the review of the Table and Fig. 1 one can conclude that substances with a high density, such as osmium, rhenium and gold have small atomic sizes.

In general, the distribution of points on the plot field, Fig. 1, shows that the relationship between the diameter of an atom and the density of a substance is very blurred (the regression equation $\rho = -3.98D\text{a} + 21.5$ with the coefficient of linear determination $R^2 = 0.226$). A more significant relationship is observed between the diameter of atomic nuclei and the density of substances ($\rho = 1.46D\text{n} - 9.55$, $R^2 = 0.403$), Fig. 2.

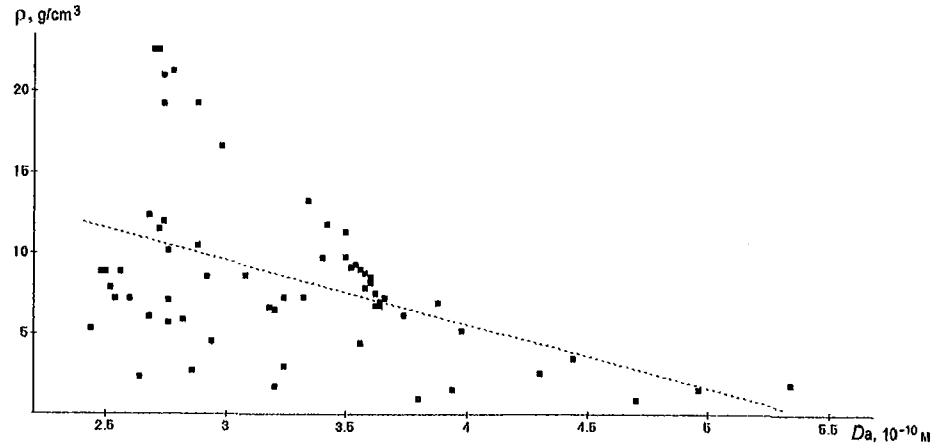

Figure 1. Distribution of the atomic diameters Da and the density values ρ of the substances.

Table. Parameters of the group of elements of the periodic table (metals and semimetals)

Element	For-mula	Atomic Num-ber	Atomic weight A	Density ρ, g/cm^3	Atom diame-ter, $Da \cdot 10^{10}$ m	Nucleus diame-ter, $Dn \cdot 10^{15}$ m	$Vn/Va \cdot 10^{15}$
1	2	3	4	5	6	7	8
Lithium	Li	3	6.94	0.53	2.90	4.96	6.93
Natrium	Na	11	22.99	0.971	3.80	7.39	7.36
Magnesium	Mg	12	24.31	1.736	3.20	7.53	13.03
Aluminum	Al	13	26.98	2.70	2.86	7.79	20.26
Silicium	Si	14	28.08	2.33	2.64	7.90	26.85
Kalium	K	19	39.10	0.856	4.70	8.82	6.62
Calcium	Ca	20	40.08	1.55	3.94	8.90	12.92
Scandium	Sc	21	44.96	2.99	3.24	9.24	23.23
Titanium	Ti	22	47.87	4.54	2.94	9.44	33.09
Vanadium	V	23	50.94	6.11	2.68	9.64	46.50
Chromium	Cr	24	51.99	7.19	2.60	9.70	52.0
Manganum	Mn	25	54.94	7.21	2.54	9.88	58.95
Ferrum	Fe	26	55.84	7.87	2.52	9.94	61.30
Cobaltum	Co	27	58.93	8.9	2.50	10.12	66.34
Niccolum	Ni	28	58.69	8.9	2.48	10.10	67.59
Cuprum	Cu	29	63.55	8.92	2.56	10.38	66.58
Zincum	Zn	30	65.38	7.13	2.76	10.47	54.65
Gallium	Ga	31	69.72	5.91	2.82	10.70	54.62
Germanium	Ge	32	72.63	5.32	2.44	10.85	87.84

End of Table

1	2	3	4	5	6	7	8
Arsenicum	As	33	74.92	5.73	2.76	10.96	62.11
Rubidium	Rb	37	85.47	1.532	4.96	11.45	12.31
Strontium	Sr	38	87.62	2.54	4.30	11.55	19.36
Yttrium	Y	39	88.90	4.47	3.56	11.60	34.62
Zirconium	Zr	40	91.22	6.51	3.20	11.70	48.92
Niobium	Nb	41	92.90	8.57	2.92	11.77	65.55
Molybdaenum	Mo	42	95.95	10.22	2.76	11.90	80.19
Technetium	Tc	43	98	11.5	2.72	11.99	85.59
Ruthenium	Ru	44	101.1	12.4	2.68	12.11	92.26
Rhodium	Rh	45	102.90	12.4	2.68	12.18	93.92
Palladium	Pd	46	106.42	12.0	2.74	12.32	90.91
Argentum	Ag	47	107.86	10.5	2.88	12.38	79.37
Cadmium	Kd	48	112.41	8.65	3.08	12.55	67.63
Indium	In	49	114.81	7.31	3.32	12.64	55.14
Stannum	Sn	50	118.71	7.31	3.24	12.78	61.33
Stibium	Sb	51	121.76	6.69	3.18	12.89	66.54
Caesium	Cs	55	132.90	1.873	5.34	13.26	15.34
Barium	Ba	56	137.32	3.5	4.44	13.41	27.57
Lanthanum	La	57	138.90	6.17	3.74	13.46	46.66
Cerium	Ce	58	140.11	6.76	3.62	13.50	51.90
Praseodymium	Pr	59	140.90	6.77	3.64	13.53	51.33
Neodymium	Nd	60	144.24	7.01	3.64	13.64	52.56
Promethium	Pm	61	145	7.26	3.66	13.66	51.97
Samarium	Sm	62	150.36	7.52	3.62	13.83	55.71
Europium	Eu	63	151.96	5.24	3.98	13.87	42.37
Gadolinium	Gd	64	157.25	7.90	3.58	14.03	60.24
Terbium	Tb	65	158.92	8.23	3.60	14.08	59.86
Dysprosium	Dy	66	162.50	8.55	3.60	14.19	61.21
Holmium	Ho	67	164.93	8.79	3.58	14.26	63.18
Erbium	Er	68	167.25	9.06	3.56	14.32	65.16
Thulium	Tm	69	168.93	9.32	3.54	14.37	66.92
Ytterbium	Yb	70	173.05	6.97	3.88	14.49	52.08
Lutetium	Lu	71	174.96	9.84	3.50	14.54	71.72
Hafnium	Hf	72	178.48	13.3	3.34	14.64	84.19
Tantalum	Ta	73	180.94	16.65	2.98	14.71	120.2
Wolframium	W	74	183.84	19.25	2.74	14.78	157.1
Rhenium	Re	75	186.20	21.0	2.74	14.85	159.1
Osmium	Os	76	190.23	22.6	2.70	14.95	169.8
Iridium	Ir	77	192.21	22.6	2.72	15.00	167.9
Platinum	Pt	78	195.08	21.3	2.78	15.08	159.6
Aurum	Au	79	196.96	19.3	2.88	15.13	144.9
Thallium	Tl	81	204.38	11.85	3.42	15.32	89.80
Plumbum	Pb	82	207.2	11.34	3.50	15.38	84.94
Bismuthum	Bi	83	208.98	9.79	3.40	15.43	93.45
Polonium	Po	84	209	9.20	3.52	15.43	84.22

The points (Fig. 2) corresponding to substances with a high density lie significantly higher than the regression line (for example, the elements aluminum, cuprum, rhodium and osmium). The points of substances (potassium,

rubidium, cesium, etc.) with low density are located below this straight line. This is explained, as noted above, by the relatively large size of the outer electron shells of alkali metals (Table).

In order to take into account the effect of the distance between the atoms of an element in the substance, the ratio of the nucleus volume to the atom volume, Vn/Va, was calculated. Assuming the shape of the nucleus in the form of a correct sphere, its volume

$$V_n = \frac{1}{6}\pi {D_n}^3.$$

Taking a similar condition regarding the shape of the atom, we obtain

$$\frac{V_n}{V_a} = \frac{D_n^3}{D_a^3}.$$

This ratio compensates for the effect of different distances between the electron shells of the atomic substance. The Table shows the calculated values Vn/Va for the group of elements (metals and semimetals). The plot, Fig. 3, shows the field of points ρ vs $(Dn)^3/(Da)^3$ of these elements.

A review of the plot reveals a high correlation between the values of ρ and $(Dn)^3/(Da)^3$. According to the averaging straight line, the dependence between the values ρ and Vn/Va is described by the equation

$$\rho = 1.32 \cdot (Vn/Va) \cdot 10^{14},\ g/cm^3 \qquad (4)$$

with a linear correlation coefficient $R^2 = 0.958$.

This is a fairly strict dependence, showing that the density of a substance directly depends on the mass of the nucleus and the volume that the outermost electron shells of atoms occupy in space. It should be noted that the nucleus mass determines its volume [5, 6]. Dependence (4) indicates a tight packing of metal atoms.

Deviations from dependence (4) towards lower density values ρ are observed in arsenicum, stibium, and especially in germanium. Germanium, arsenicum and stibium are semimetals. The positions of individual points of elements that do not lie on the generalized straight line (4) can be explained by non-sphericity of the nucleus and atom shape, the different number of electrons in the outer electron shell of the atom, etc.

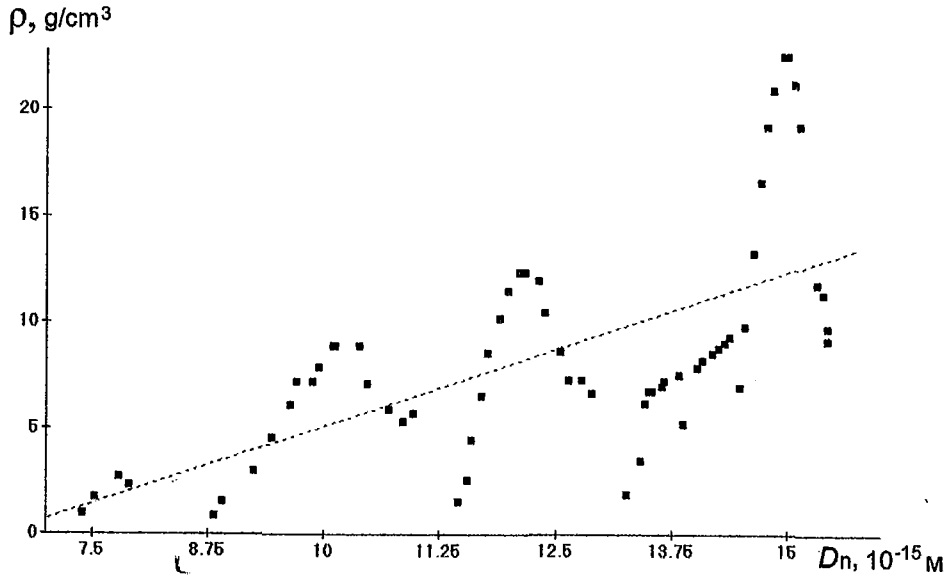

Figure 2. Distribution of the diameters Dn of the atom nuclei and the values of density ρ of substances.

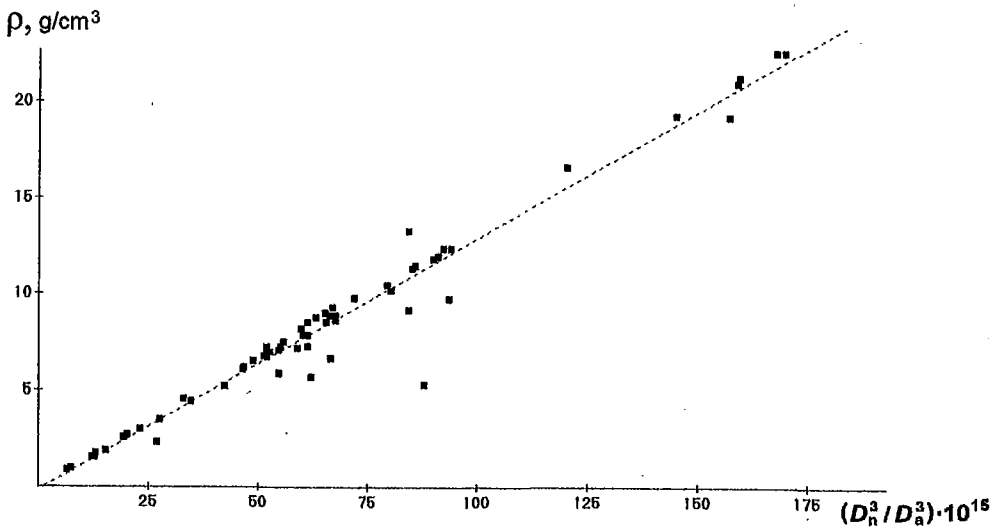

Figure 3. Distribution of the ratios $(Dn)^3/(Da)^3$ and corresponding density values ρ of substances (metals and semimetals).

Dependence (4), in general, confirms the conclusion that the shape of the atom and the nucleus for many elements is close to spherical. The approximation of the points on the graph, Fig. 3 in the form of a straight line indicates that the dependence (4) is equally suitable for both light and heavy elements. The dependence (4), as a whole, establishes a causal relationship between the macro value - density, nucleus mass and atom size.

Declaration of Competing interest.
The author declares that he has not known competing financial interest or personal relationships that could appear to influence the work reported in this paper.

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TIME AND THE QUANTUM
PART 1; TIME-ONLY PHYSICS

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Abstract

While obviously correct, our physics suffers from two sets of philosophical difficulties, the large set associated with quantum mechanics and the other involving the nature of time, the source of its flow. These are shown here to be two sides of the same problem. Time is the last operationally-defined concept in the foundations of physics and thus the only one entitled to have different scales of measurement and arbitrary units. This is only possible if it is discontinuous, the repeating phenomenon counted to measure time providing the unit of a particular scale. An unexplored consequence is that the only change that might resolve all the philosophical difficulties of physics without affecting its proven substance is to try different scales, perhaps from other sciences. Our practical unit, a vibration of the cesium atom that tells us "the time" despite having no theoretical significance, is supplemented by **natural** units that are appropriate in some situations and tell us about time itself. Part 2 presents the proof for this view by demonstrating a scale that embodies the essential features of a past, present and future, and that reduces all the puzzles of the quantum to common sense, albeit at the cost of accepting the limitations of the human brain.

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Introduction

These papers present a completely new and epistemological interpretation of the quantum, one that does not require God to play dice and that simultaneously resolves the philosophical difficulties of time in physics. The argument is necessarily unconventional and multifaceted, so a brief summary is in order here lest the reader fear it will drift off into exotic philosophies. Although it takes a short step outside physics, the argument remains firmly within science, even (at least in an order-of-magnitude sense) quantitative science.

Why is it that our physics can only explain some 5% of the matter in the universe? Consider the hypothesis that it is a consequence of the undoubted but unwelcome (to the physicist) fact that the amount any intelligent species can learn about reality must be constrained by the power of their brains. Given only the computational theory of mind, this power can be quantified by the speed at which the brains process information, $1/\tau$ bits/s, where τ is the neurological time constant, the **average** time between bits. If the hypothesis is correct, the human value of $\tau \approx 10^{-19}$s must be hiding somewhere in our physics, and it has already been found in a highly significant location at the heart of quantum phenomena (1; or see part 2). When expressed as a length, $c\tau$, it is the size of atoms, while as an energy, h/τ, it is close to the rest energy of the electron. This makes τ the obvious candidate for the missing connection between quantum reality and the "consciousness" of the observer required by the conventional Copenhagen interpretation. Could our inherently uncertain knowledge of quantum phenomena be just the first symptom of our neurological limitations?

Investigation of these heretical ideas starts with an original solution to physics' other great philosophical difficulty, the nature of time. The International Bureau on Weights and Measures (henceforth known by its French initials as the BIPM) recently decreed that time is to be the last operationally-defined concept in the foundations of physics. An unexplored consequence is that time becomes the only concept entitled to different units and scales of measurement, but what does "different scales of time" even mean? Setting aside centuries of inconclusive philosophical speculation, the metrologists have announced that time is **just** the thing measured by clocks, but clocks are just machines for counting, and the repeating phenomenon that is counted constitutes the unit of the time scale defined by a particular clock. Physics here becomes an internally consistent system of logic, what we get by studying reality using the scientific method and **physical** clocks, but it cannot preclude time scales based on other sciences that may be more appropriate in other circumstances. The unit specified by the BIPM so that we can all agree on "the time", a certain vibration

of the cesium atom, is an excellent practical choice but it has no fundamental significance. The only freedom we have that leaves the substance of physics unaffected is to complement it with **natural** units that embody time itself, even if the corresponding clocks are purely conceptual devices.

There are two such units. The natural unit for objective reality and the laws that describe it is the Planck time, its small size accounting for the success of the assumption that time is continuous for all purposes short of quantum gravity. The apparent reversibility of time in the theories of physics reflects the absence of any inherent arrow from the objective scale, here called Ptime, that results from counting such increments. But the observations of reality that validate the laws are acts not of physics but of neuroscience, acquisitions of information by the observer's brain. They work on a personal time scale, Wtime, that counts the bits of information processed in the individual's brain and that ticks forward by one unit of τ for each one. It quantifies the "psychological" arrow of time, which is why time flows in its familiar irreversible fashion in all experiments despite appearing to be reversible in the theories. The macroscopic world floods our brains with so much information that Wtime is usually also effectively continuous and thus indistinguishable from Ptime (except for its irreversibility). But in the quantum regime information is so sparse that the discontinuity of Wtime becomes significant, which is why the "act of observation" becomes philosophically traumatic in quantum mechanics.

The logical but untried solution is to include a parameter to describe the observer but, since this is forbidden by the rules of physics, the argument must proceed in the next best thing to complete objectivity, a new field (physics+τ) located on its border with neuroscience. In this logic, the discontinuities we experience as quanta are a reflection of the τ-sized discontinuities in Wtime that result from the discrete nature of the information processed by our brains. The Copenhagen interpretation forces physicists into the questionable belief that the act of observation somehow creates the piece of reality that emerges, be it a wave or a particle; in (physics+τ) all it creates is a time increment of τ, the NOW in which the observation happens.

The goal of (physics+τ) is to describe not so much how reality is as how much a species of a certain brain power can be expected to learn about it. In our science fiction those large-headed aliens always have better technology than us because they are smarter, but our actual science lacks a field that relates a species' brain power to the sophistication of its physics. This is the gap that (physics+τ) fills and, since τ appears as a variable, putting in values smaller than ours may give some clues on how to improve on that 5%. While making no difference to the substance and practice of physics, (physics+τ) sits alongside it

providing a new perspective on our interaction with reality and thus on the philosophical difficulties of human physics. The proof given in part 2 is that this logic, with time flowing along in those quantum-sized ticks of τ, reduces all the familiar puzzles and paradoxes of quantum mechanics to common sense. The reader may object that Von Neumann and others have proved quanta to be ontological phenomena, a part of objective reality, but these proofs were based on conventional assumptions about the continuity and objectivity of time that are called into question here.

A Scheme of Physics

Resolving the philosophical difficulties at the frontiers of physics requires starting again from the beginning, so this work is based on a logical but unorthodox scheme for the history of the subject. It can be illustrated by the idea of volume, not some particular volume or some unit of volume but the concept itself. It must have originated in what the Germans call our umwelt, the collection of senses and neurological pathways through which we interact with reality. This allowed our ancestors to notice that some things are bigger than others, but such vague personal perceptions were of no help to those trading in grain or distributing water for irrigation. One of the essential bureaucracies of any civilization, a Bureau of Weights and Measures, therefore turned volume into an objective quantity by giving it an operational definition, the standard bucket. The resulting units of measure, things like the gallon and the bushel, were arbitrary, but they allowed all members of a civilization to agree on the answer to the question "What is the volume?". Only then could some forgotten genius (it may have been Archimedes) take up the deeper question "What is volume?". In what may have been the first great theory of physics, he reasoned that it is a measure of the amount of space. Since space is defined by three lengths, given a unit of length like the cubit, volume has natural units of the cubic cubit that reflect its true nature.

In our scheme all great advances in physics involve the same sequence of events. The concepts on which it is based, weight, length, heat, time and all the rest, originate in the human umwelt and became measurable physical quantities (albeit with arbitrary units) only when they are given objective operational definitions in the form of balances, yardsticks, calorimeters and clocks. Einstein was right to describe them as "free creations of the human mind". If human physics is seen as a system of logic, they must be listed among its axioms, the "truths accepted without proof" on which the system is based. The snag is that there is no reason to believe that Mother Nature cares what

concepts may be thrown up by our specifically human sense perceptions. A race of intelligent dolphins, for example, would not share our concept of weight because in their natural environment they are weightless. On the other hand, electric charge would appear much earlier in their physics than it did in ours because they can detect it directly in that environment. The foundational concepts of scientific races of dogs, bats or hypothetical intelligent aliens can be left to the readers' imaginations. However, since we all share the same reality, if we follow the scientific method and do our experiments correctly, we must all eventually reach the same description of it. It follows that the laws of physics with which we describe this objective reality must also serve to eliminate the species-specific list of axioms on which the enterprise is based.

This is demonstrably true for us humans. Our scheme defines a great theory as one that eliminates one of these operationally-defined axioms by explaining its true nature in terms of the presumably more fundamental concepts that remain, and thus replaces the old, arbitrary units with new, natural ones that reflect this new knowledge. Newton, for example, is rightly celebrated because, while developing the laws of mechanics, he clarified two of those axioms. He first explained weight as the force exerted by the earth's gravity on the mass (a more fundamental concept) of an object. Then he explained force as mass×acceleration, giving rise to the natural unit now named in his honor.

Another good example is the concept of temperature. It clearly originated in our umwelt, but the sense perception is unreliable; warm water feels hot to a hand that was just in cold water but cold to one that was just in hot. An objective operational definition requires three more-or-less arbitrary choices, two fixed points and a standard type of thermometer to interpolate between them. The first to try it was Gabriel Fahrenheit (1686 – 1736). He chose his lower fixed point logically enough as the coldest thing he knew how to make, a mixture of ice and salt, but then seemed to get side-tracked by the idea that the upper fixed point should have some actual significance (At one point he suggested using the temperature of the human body, which would have set medical science back centuries). It was Anders Celsius (1702 – 1744) who understood that, when making arbitrary choices, simplicity is best. Put a mercury-in-glass thermometer in ice water and mark the level, then put it in boiling water and mark that level. Now divide the distance between the two marks into 100 equal increments and *voila*, you have created an objective, reproducible scale of temperature that allows all the members of your society to agree on an answer to the question "What is the temperature?".

Among the many interesting consequences of the great theory of Statistical Thermodynamics was the answer to the deeper question "What is

temperature?". It is a measure of the vibrational energy of molecules, a concept with natural units of Joules per mol. The theory created the new natural scale of Kelvins which has a definite, non-arbitrary lower limit, absolute zero. One of the tasks of the BIPM is to specify a range of standard thermometers to actually measure temperatures from there up to thousands of degrees, but this task is very different from that facing Celsius. Far from being arbitrary, the choices must be made to give the best practical fit to the ideal theoretical scale.

In our scheme the *sine qua non* of a great theory is the introduction of a universal constant, the relevant constant here being that of Boltzmann, k. It has units of Joules/mol °K and is now used mainly to convert the measured scale of Kelvins into the natural units of Joules/mol, but its main significance in our scheme is that these are the units of the concept of entropy. It follows that any entropy can (indeed should) be expressed as a naturally dimensionless number, a multiple of k. It is a pure number, untouched by those products of the human umwelt, something very different from those operationally-defined quantities; we cannot sense it or measure it directly; there is no such thing as an entropy meter; it was not a starting point for our physics but something that emerged from its progress. What the great theory of Statistical Thermodynamics actually did to the structure of physics was to eliminate one human-derived concept, temperature, by revealing its true nature, and to introduce another, entropy, that Mother Nature finds important for her own description. This was progress.

Another theory, the Second Law of Thermodynamics, tells us about the significance of entropy. It does not qualify as "great" in our scheme because it does not introduce a universal constant, only explaining the significance of the constant produced by one that does qualify. Almost all great theories have such a theory associated with them in a similar way, and they will be called auxiliary theories. The general theory of relativity, for example, fits into the scheme as the auxiliary theory associated with Newtonian mechanics. It shows why the gravitational mass, the m in his law of gravitation, is the same as the inertial mass, the m in his Second Law.

Where are we Now?

The goal of physics is a complete and objective picture of reality, one that is free of the preconceived notions, sensory acuity, brain power, religious beliefs, or any other purely human characteristic. The number of concepts that must still be defined operationally, the number of axioms in the logic system of physics, is a measure of how far we are from that goal. Our scheme thus provides a quantitative measure of the state of physics at any time in terms of the ever-

decreasing number of concepts that must be defined in this way and that can be recognized by their arbitrary units. By the hey-day of classical physics in the 19th century this number was down to three, mass, length, and time, and many believed that the subject was complete. It is said that Planck's high school teacher tried to dissuade him from going into physics on the grounds that there were no more interesting problems left to solve! Who could doubt a logic system based on such self-evident axioms? It took an Einstein to realize that, far from being fundamental, mass, length and time all depend on how fast you are going.

Since then there have been two more great theories, each with its own universal constant and auxiliary theory to describe the significance of concepts with the units of that constant. The first was embodied in Maxwell's equations that introduced the speed of light. Its auxiliary theory was the Special Theory of Relativity, which showed the profound consequences of the fact that the speed of light, c, is in fact a universal constant and not just a speed like any other. Then came quantum mechanics, with Planck's constant, h, which has the units of action (energy×time) and that, like entropy, is something we can neither sense nor measure directly. The associated auxiliary theory, the Principle of Least Action, had been known for decades by the time of Planck et al., but there is no rule that says intellectual progress must proceed in neat chronological order. It is not a coincidence that Feynemann was able to construct a popular interpretation of quantum mechanics around this principle.

Since each of these theories can eliminate one from our list, physics can now be based on $3 - 2 = 1$ operationally-defined axiom. The difficulty is that neither of these last two great theories were clearly about mass or length or time in the same way that Statistical Thermodynamics was clearly about temperature. The correct procedure is therefore to select not the two operationally-defined axioms that are to be eliminated but the one that is to be retained as the last such concept in the foundations of physics. Which one should be chosen?

There are many good reasons for choosing time. The nature of time remains a problem in physics, the laws working equally well whether it goes forwards or backwards, while in experiments it only goes forwards. If we are to sort this out we need to keep time where we can see it. Recall all those dolphins, bats and aliens whose physics started from different concepts but which, under our scheme, must all finish up with the same one. While it is possible to imagine intelligent species not sharing our concepts of weight or temperature, it is impossible to imagine one that does not share our concept of time, since without it there can be no cause and effect. The only way of telling them apart is that causes must happen before their effects and, without the flow of time, that "before" is meaningless.

However, the best reason for choosing time is that the global body responsible for such decisions, the BIPM, has already made the decision for us. In 1983 it redefined the meter from a certain number of wavelengths of laser light to the distance travelled by light in a vacuum in 1/299,792,458 seconds, an act that eliminated the need for a separate operational definition of length, fixed an official value for the speed of light at c=299,792,458 m/s, and simultaneously demoted it to the status of a conversion factor between those old units of meters and the new, natural ones of light-seconds. They have recently done the same for mass, abandoning their standard kilogram (a lump of platinum-iridium alloy they kept in a basement in Paris) on the grounds that it may have gained or lost a nanogram here or there without any way of knowing. They replaced it with a procedure to, in Robinson's (2) words, "quantify the mass m in terms of the Planck constant plus the meter and the second", which involved fixing an official for Planck's constant.

This leaves time, the thing measured by clocks, as the last operationally defined concept in the foundations of our physics and, in our scheme, this is as far as physics can go. Any process of explaining things in terms of other things must stop at one since this last one could be explained in terms of . . . what? Furthermore, if a new great theory were to appear, it would leave the logic system of physics with no axioms of its own, making it indistinguishable from the logic system of mathematics that provides the language in which its laws are expressed. So, in our scheme, this time-only version endorsed by the BIPM is the culmination of physics. It has satisfied William of Occam's injunction not to multiply entities beyond necessity. The subject is now unified in the sense that it has been reduced to a single operationally-defined axiom, and an axiom is something that can be taken for granted within its system of logic, something that can certainly be said about time in physics.

The problem is that our physics does not feel complete. 95% of the matter in the universe remains "dark", meaning unexplained by our science because invisible to our senses and instruments. Furthermore, while quantum mechanics is undoubtedly correct, it is far removed from common sense and remains stubbornly incompatible with the other fundamental theory, general relativity. A detailed examination of time-only physics provides a new perspective on these difficulties.

What is Time?

While scientists, philosophers, theologians and many others agonize over the nature of time, the metrologists of the BIPM have quietly provided the

answer. Time is the last operationally-defined concept in the foundations of physics. It is, and will always remain, just the thing measured by clocks. As such time is the only concept entitled to have different scales of measurement and arbitrary units, the source of much confusion being that time is almost the only concept that has never had these things. When the Bureaus of Weights and Measures in all those ancient civilizations were fixing their own units of length and weight, they all had the same unit of time thrust on them by the motion of the planet they shared, the day. How this got chopped up into our common unit of the second is a subject for the history books, but anything that depends on the fact that the ancient Babylonians used a hexadecimal number system can only be described as arbitrary. The second was officially defined as 1/86,400 of a day as late as 1967, thus perpetuating the common illusion that time is somehow an astronomical phenomenon.

As is often the case, progress requires asking the right question. Since time is doomed to remain operationally defined, what is the operation that defines it? The answer is simply counting, an act that generates a sequence of numbers that increase monotonically in the direction we know as time. If I ask you to count backwards from ten you know what I mean without further explanation; "backwards" means backwards in time. Clocks are just machines for counting, and they can do this only because we build into them the most basic feature of any computer, including our brains, a memory. Just as I could not count to 3 if I could not remember that the previous number was 2, so a mechanical clock could not work without a mechanism for keeping the fingers stationary until it is time to add the next tick. Modern clocks perform the same task electronically.

The repeating phenomenon that a clock counts provides the unit of its particular time scale. Progress in timekeeping involves the improved precision that has resulted from counting ever smaller units, from the swing of pendulums, to the buzz of piezo-electric crystals, to the inaudible vibrations of the cesium atoms in the BIPM's official clocks. Call this scale that is actually measured, a count of these units, ctime, or in those arbitrary but socially useful seconds, Ctime $=t_c \times$ctime, where $t_c=1/9,192,631,770$ s by decree of the BIPM. This is an excellent practical choice, cesium atomic clocks being very precise, robust, and unaffected (within reason) by changes in temperature, gravity etc. But it must be clear that this time unit, t_c, has no theoretical significance. Its importance here is that, as the last human choice in the foundations of physics, it is the only thing we are free to change in our quest to clarify the philosophical difficulties of physics without affecting its proven substance.

An accurate measurement is one that properly quantifies the concept in question. We can have accurate thermometers because we know the answer to "What is temperature?", but there is no such thing as an accurate clock. For the purposes of doing science and organizing the activities of our global society, we must have objective standard clocks whose readings provide an agreed answer to the question "What is the time?". The BIPM provides such clocks, but general agreement should not be confused with accuracy: they do not tell us "What is time?". Note also that these clocks are far more precise than necessary for the social function of time. The shortest interval of which we are consciously aware is some 10^{-2}s, corresponding to the two decimal places on your digital watch. There is no such thing as a sense perception of times shorter than this, a fact that becomes significant in part 2.

Matters Arising

This time-only approach throws up several interesting observations that cannot be pursued in detail here.

The idea of time-as-counting automatically implies that it is discontinuous; only the integers count and, as Kronecker said "God created the integers, all else is the work of man". We learn calculus as callow youths, are impressed by the apparent ability of those d/dt terms to predict the future, and promptly swallow the assumptions on which it is based. But the success of calculus does not prove that time is continuous, only that, if it isn't, it comes in ticks much shorter that the smallest increment which can actually measure, officially $t_c \approx 10^{-10}$s but unofficially improved to $\approx 10^{-15}$s by some clever makers of cesium atomic clocks. A clock that counts off the infinitesimal increments needed for continuity is inconceivable, and yet we know that the assumption of continuity works well in all situations short of quantum gravity. It follows that in that large gap between the tick of our official clocks and the $(1/\infty)$ of the hypothetical continuum clock, there must be a limit to the precision of time, the natural time unit of reality itself.

Counting must not be confused here with number. A statement like "There are nine cows in that field" is just about number and conveys none of the sequentiality, the "one damn thing after another", that is the essence of our experience of time. But in the act of counting the cows our minds superimpose an order on them that they do not actually possess. Indeed, if counting is difficult because the cows are all alike and are all milling around, it may be necessary to

actually go into the field, paint a 1 on the first cow encountered, a 2 on the second, and so on. This provides a metaphor for the interaction between reality, time and the observer that will emerge here. Reality just sits there like the cows in no particular order until we observe it and, by doing so, superimpose our notion of the passage of time upon it.

The idea of time-as-counting gives a new perspective on the much-debated connection between the fields of physics and mathematics. A question that worries many thoughtful physicists is why their subject describes reality in the language of mathematics, but this is much easier to understand if physics ultimately reduces to time, which ultimately reduces to counting. There is even an answer to a puzzle raised earlier, that the logic of physics must have at least one axiom of its own to distinguish it from pure mathematics. It is that mathematics is actually based on number, while counting and the time it creates belong together in the logic of physics. The feature that separates counting from number, the sequentiality of the number system (i.e. why 1+1=2), was certainly a major issue in Russell and Whitehead's ultimately failed attempt to reduce mathematics to pure logic (3).

In 1967 the responsibility for timekeeping finally passed from the astronomers to the physicists. We went from using the universe to put our clocks right to using our clocks to put the universe right, a useful reminder that time is not some idea in the mind of God but just what your society says it is. While this change went largely unnoticed it must have altered something, but what? Suppose that we fix the day by observing the sun and time it in ctime, an archetypal science experiment, careful observation of reality to fix the number of cesium atom vibrations in a day. But repeating the experiment on the same day every year for a few decades will produce a disconcerting result, a slow but steady increase in the dimensionless number (Day/t_c). What does this mean? Nowadays we interpret it as showing that the earth's rotation is slowing down, but before 1967 that was literally unthinkable, the merest scientific gobbledegook. Back then the day was the BIPM's official "constant interval" of time and the earth's rotation rate was constant at exactly 1 per day not as a result of theory or measurement but of definition. Anyone pondering our experimental result back then would have been forced to ask why those cesium atoms were speeding up. The moral here is that although changing our unit of time cannot change experimental results, it can change how those results are interpreted. This is however exactly what quantum mechanics needs: there is no doubt about the experimental results, but might there be a time scale in which they make sense?

The Many Time Units of Physics

It is a commonplace observation that the laws of science are expressed in their most concise and universal form as relationships between dimensionless numbers, and the scheme described above explains why this is so. Here the concepts involved, mass, length etc. are not characteristics of reality, but human sense perceptions that we have quantified in order to describe reality to ourselves. Progress towards an objective description thus involves getting rid of these concepts, which physics has done in a series of great theories. But dimensionless numbers perform a similar function with much less effort, simply by arranging the variables into groups from which the concepts cancel out. A law of science is then indistinguishable from a mathematical equation since the terms in it are pure numbers with no units.

Time-only physics allows only two types of such number; there are naturally dimensionless concepts such as entropy and action that can be expressed as fractions or multiples of the universal constants, but all the rest **must** have the form (T/T), the ratio of two times (note that speed falls into both categories). It follows that the laws of time-only physics must be reducible to a set of relationships between such numbers. They provide its proper mathematical formulation, and they are recognizable in the writings of physicists who have looked most deeply into the problem of time. Since a ratio of two times is not itself a time, just a number, they satisfy Rovelli's desire for "a physics without time" (4). They also connect with the work of Barbour (5) who peered deeply into the laws of physics and concluded that they are not so much about time *per se* as how fast one process goes relative to another, which is another way of saying that their subject matter is not some abstract "t" but these (T/T) numbers. However, his conclusion that time does therefore not exist is scientifically untenable. Time is the best-proven concept in science, since it flows along in its familiar irreversible fashion in every experiment ever conducted.

Kant (quoted by Magee (6)) always maintained that our working definition of that "t" in the laws of science is "You know what I mean". We do indeed know, because we all share the perception of the passage of time and our society has specified how we must measure it. When a society chooses its official unit of time, the small sub-set of those (T/T) numbers that have it in the denominator acquire a new status; they become **measurements** of time. Thus, the quantity that our atomic clocks actually measure, ctime, the number of cesium atom vibrations in an interval "t", is actually the ratio (t/t_c) where

t_c=1/9,192,631,770s is that last purely human choice in the foundations of physics.

Scientific consistency surely requires that the quantity appearing in the laws must be the one we actually measure, and it is significant that enforcing this rule makes no difference to the equations. On the other side of the equation from that "t" there must be another quantity with units of time, the time constant of the system under consideration, Θ, the half-life of an isotope, the reciprocal of the natural frequency of a dynamic system, the doubling time of a microorganism etc. This too should be normalized by t_c, which immediately cancels out. The equations acquire their most concise form if that "t" is normalized not by t_c but by Θ, thus producing a number (t/Θ) from which that human invention, t_c, has vanished and in which Θ appears as the unit of the time scale appropriate for the system. Consider, for example, the heating or cooling of a sphere. Here the time constant Θ is (R^2/α) where R is the radius of the sphere and α the thermal diffusivity of its material. It should strictly be written as $(R^2/\alpha)/t_c$ but, when it is divided into our measured time (t/t_c) the t_c cancels out, leaving a new number $(t/(R^2/\alpha))$, that embodies a time scale that is the natural one for this system, being the same for all spheres from cannonballs to plastic beads.

Many of these systems form the basis for practical clocks. Sciences like geology that deal in long spans of time employ the half-lives of long-lived isotopes as their Θ. For a pendulum clock Θ would be its period, P, which is given by a law that provides a simple example of our (T/T) numbers;

$$P/(l/g)^{1/2} = \text{some function of the swing angle} \qquad (1.1)$$

The reader can doubtless conceive of a clock in which the tick is provided by the time $(2l/g)^{1/2}$ required for an object to fall a distance l from rest in a gravitational field g. When the swing angle is small the function in equation 1.1 becomes a constant, making the ticks of the two clocks proportional to each other. By means of suitable gearing behind the dials both can then be made to display that same time "t" with which we are so familiar. But in reality the function is never **exactly** constant, and both clocks must have a little knob on the back so that they can be "put right". But "right" does not mean anything beyond agreement with the BIPM's official cesium atomic clock, the only one that does not have such a knob.

To conclude, the conventional wisdom accepts that the units in which we measure time is a bureaucratic decision, and that non-equilibrium systems all have their own time constant. But in the wisdom of time-only physics there are

many possible units, and the time constant provides the appropriate unit for the specific system. This immediately suggests new questions; does reality have its own **natural** unit of time? Are there **natural** time scales that embody its flow?

Natural Units of Time

Another benefit of our scheme is that it removes the confusion about the status of the universal constants expressed by Barrow and Tipler (7);

The Boltzmann constant is merely a conversion factor between energy and temperature units, and not a fundamental constant having the same status as G (the gravitational constant), h (Planck's constant) and c (the speed of light).

Surely all such constants must be one thing or the other, either "fundamental" or "conversion factors", and in our scheme they are all the latter, allowing us to express all our concepts in time units. (The idea that these constants may be different in different parts of the universe, or in other universes, becomes unthinkable). In time-only physics the last few operationally-defined concepts, length, energy and mass, thus become;

$$t_l = l/c \ldots (a) \qquad t_e = h/E \ldots (b) \qquad t_m = mG/c^3 \ldots (c) \qquad (1.2)$$

Give or take some small constants that can be ignored for our purposes, 1.2(b) can be recognized as Planck's equation, the equation at the heart of the last great theory, quantum mechanics. While there is no doubt that it is correct, there has always been something suspicious about it. The whole point of quantum mechanics is that energy comes in discrete chunks called quanta, so how can it be equated to the supposedly continuous concept of time? Physics, of course, has answers to this question, but they lead into the myriad complexities of the subject, particle-wave duality, collapsing wave functions, complementarity etc. The great advantage of this work is that it by-passes these complexities by treating equation 1.2(b) as **just** the relationship between our concepts of energy and time.

Our insistence that time is not continuous might seem to eliminate those suspicions about Planck's equation, but it also introduces a new and unexplored question. While length (1.2(a)) and mass (1.2 (c)) acquire units of time, Planck's equation reduces energy not to a time but to an inverse time, a rate or frequency. This will prove to be the single most important fact in this work, but it begs the

curiously unexplored question of what "frequency" actually means in a world of discontinuous time scales.

Given that there can be many discontinuous scales of time created by counting different units, the next question must be whether there are natural scales of time as there are of everything else and, if so, how can they be found? Consider a jogger with a digital watch whose "seconds" display is broken, leaving the minute as her effective unit of time. She times her jog in minutes and, when she has finished, measures her heart rate by counting the number of beats in a minute. Now consider a question so trivial that it is taken for granted in a world where time is assumed to be continuous: why are there these two kinds of measurement, one of time and the other of a rate or frequency? The answer obviously depends on the relationship between the phenomenon being measured and the prevailing unit of time. Her jog takes longer than her unit, making its duration a time-like concept measured by counting the minutes, but her heart beats faster than the unit, making it a frequency-like concept, measured by counting pulses in one minute. In our world of operationally-defined discontinuous time it must be a general rule that the prevailing unit is the shortest interval that can be measured as a time; shorter intervals must be quantified as a frequency, a count of something in one unit. So what separates time-like measurements from frequency-like ones is the prevailing unit of time. In time-only physics, natural units of time can thus be found where naturally time-like concepts (length, mass, etc.) bump up against a naturally frequency-like one (energy). There are two such units. One, the natural unit for objective reality and the theories that describe it, appears below. The other, the natural unit for the observations of reality that validate the theories, is the subject of part 2.

Incidentally, in his early experiments, Galileo used his pulse to time the swing of a pendulum. Nowadays we do it the other way around (i.e. we imagine the (T/T) number the other way up) but that does not invalidate the idea of a personal time scale based on a count of heartbeats, htime. It is the appropriate scale for joggers, a fast (in htime) jog resulting from fast (in ctime) running and/or a slow (in ctime) heart rate, both of which indicate good cardiovascular fitness. Those heart-rate monitors employed by some joggers are essentially htime clocks, but they confuse the issues by reporting their measurements as a "rate at an instant" without defining what they mean by "an instant". A pulse count over a period of one second, for example, would be either 0, 1 or 2, which is not very helpful.

Mass, Energy and the Planck Time

Having seen films of nuclear explosions, we are accustomed to the idea that mass and energy are the same kind of thing, and the most startling consequence of time-only physics is that this cannot be so; mass is a time-like concept while energy is a frequency-like one. This should not come as a complete surprise since we do not talk about them in the same way. We keep "mass" for big things like planets whose behavior is governed by the force of gravity; hence the gravitational constant in the definition of mass-as-time in equation 1.2(c). We use "rest energy" for small things like electrons whose behavior is governed by quantum mechanics and is not significantly affected by gravity; hence the use of Planck's constant in 1.2(b). In time-only physics the relevant equation $E=mc^2$ becomes;

$$t_e\, t_m = t_p^2 \qquad (1.3)$$

where t_p is the Planck time $(Gh/c^5)^{1/2} = 1.35\times10^{-43}$s

To find what separates mass from energy suppose that our time-only physics were to include times shorter than t_p. In this region $t_m<t_p$ would make m less than the Planck mass $m_p=(hc/G)^{1/2}= 0.055$mg, while a little simple algebra shows that $t_e<t_p$ would make $E>m_pc^2$, the energy equivalent of m_p. Since energies being bigger than masses is the wrong way around, equation (1.3) is only consistent with our use of the words if the Planck time is the shortest possible increment of time, and the concept of mass is reserved for things heavier than the Planck mass, anything lighter being properly called energy.

In our scheme the concepts of our physics originated in the human umwelt, but these sense perceptions were eliminated one by one as the subject progressed towards complete objectivity. In the culmination represented by time-only physics there should just be the one left, but might others still be lurking in its structure? The concept of mass must have originated when some ancestor picked up and threw a stone, feeling the heft of the object though the nerves of their hand. The most basic form of energy is heat, which as a sense perception results from the cumulative effect of zillions of molecular impacts on our skin, none of which we can feel individually but experience collectively as the comfortable blur of "room temperature". The umwelt's dividing line between mass and energy would thus logically be the lightest object we can detect as an individual object on our skin. A clue to its size is provided by the flea, which has evolved so that it can land on our skin undetected until it bites. While the mass of a flea is a vague number, it is indeed in the ballpark of the Planck mass which is that of a 0.3mm grain of sand. The difference between

mass and energy was thus a contribution of our umwelt, albeit one that Einstein eliminated even before it was recognized as such. Other such relicts of our sense perceptions will appear, and will be duly eliminated, in part 2.

Ptime

The Planck time is the only quantity with units of time that can be constructed from Mother Nature's universal constants and, as such, was always the prime candidate for her natural unit of time. This has now been proved. Equation 1.2(b) shows that energy is a naturally frequency-like concept while 1.2(c) shows mass to be a naturally time-like one, and what separates them is the Planck time. It follows from the jogger's rule that t_p is indeed a natural unit of time.

A count of these natural increments will generate a natural scale to be called ptime or, if we insist on those arbitrary units of seconds, Ptime=t_p×ptime. This can be identified with that "t" in the laws of physics, being completely objective and, since t_p is so small, effectively continuous. It is however a purely theoretical scale; no-one is ever going to build a real clock that ticks off increments of t_p. Time in physics thus strictly means Ptime as approximated in practice by Ctime, and the two will be the same (except for the smallest increment they encompass) if every vibration of every cesium atom contains the same number of Planck times, that is if the number (t_c/t_p) is always and everywhere a constant. This is not an unreasonable assumption on which to base our physics but, since that number is an integer (all ptimes are integers) with 33 significant figures, it is not amenable to experimental proof.

Among the best evidence for this Ptime is its agreement with Smolin's work on quantum gravity (8). He has shown that such a theory can only exist if time is not continuous and, in his theory, space-time does indeed become discontinuous at the Planck scale.

Conclusions

In our scheme of physics time now has the same status as that of temperature before the progress of physics explained its true nature. Back then °F, °C and others really were different, somewhat arbitrary scales of measurement, and selecting one of them allowed a society to agree on the answer to "What is the temperature?". But the great theory of Statistical Thermodynamics then both answered the deeper question "What is temperature?", and introduced the natural (if purely theoretical) scale of Kelvins.

Similarly, time is now defined operationally by the act of counting, which makes it necessarily discontinuous and may provide clues to the mysterious connection between physics and mathematics. The unit of a scale, the repeating phenomenon that is counted, is arbitrary and can come from any branch of science, and once a society has agreed on one it can agree on the answer to "What is the time?". The difference between the two cases is that no-one expects a new great theory to appear with the answer to the deeper question "What is time?". Consequently, all those different time scales are not right or wrong, only more or less appropriate in a given situation.

To illustrate the point, imagine a planet that orbits its sun in the same way that the moon does the earth, with the same side always facing inwards. Inhabitants of this side of the planet (the dark side would presumably be unable to support life) would live in perpetual daylight, their sun absolutely stationary in the sky. If they were intelligent, they would know **about** time in its thermodynamic sense of things (including themselves) wearing out and in its neurological sense of a shared past that they remember, but they would have none of those astronomical clues that provided our ancestors with their "constant intervals" of time, no day or night, no phases of the moon or stars moving across the sky, not even a profession of astronomy unless they organized expeditions to the dark side. What would these people count in order to quantify time? They might try their heartbeats, the htime scale, but individual htime could not perform the main societal function of a time scale, coordinating the activities of its members. Our aliens could overcome this difficulty in the same way that our ancestors dealt with units of length like the cubit and the foot. Arguments about whose arm or foot was to be used were settled by choosing the king as a standard, so let the king's "standard" htime be transmitted to suitably large dials scattered around the kingdom. In the absence of anything like our day and night the work "day" might be fixed at 30 kkb (kilo-king beats). You might object that the workers would notice that some such "days" seemed longer than others, but a little reflection will show the flaw in this argument. You notice that some of your workdays seem longer than others but this does not undermine your faith in your society's clocks, only in your personal perception of time.

It is hard to imagine this king's-htime society developing physics. Anyone trying to measure, say, the period of a pendulum of length l would find that their results (in kb) would vary apparently randomly, although actually in accord with the king's exertions. But at the next bench may be someone measuring the time (again in kb) for an object to fall a distance l under the planet's gravitational acceleration, g. If they were to compare notes, they would notice a similar pattern in those apparently random fluctuations, divide one set

of results by the other and EUREKA, they would have discovered the (T/T) dimensionless number from equation 1.1. Their science would never look back once it had canceled out that irrelevant king's heartbeat and learned the point being made here, that the laws of physics are what you get when you study reality using a physical operation as your unit of time.

There are many such clocks available and, just as the BIPM must specify a range of real thermometers that approximate the theoretical Kelvin scale in practice, so it must choose one standard clock to approximate Ptime. The first problem of time in physics is just how crude and imprecise these cesium atomic clocks are when set against the tick of reality. Is this the best that human brains and their vaunted technology can do?

The second problem is that the laws of physics are reversible in time, working equally well whether it goes forwards or backwards. This is more serious than sometimes portrayed because the truth comes not from theories but from experiments, and time flows in its familiar irreversible fashion in all experiments. Experiments necessarily involve an observer, and their time only goes forwards because their memory tells them about an ever-growing past, that includes information about the outcome of the experiment (it is a trivial version of this memory that we build into our clocks to enable them to count). The relevant organ for the passage of time is thus not the heart, with its htime, but the brain with its corresponding scale.

Some would appeal to the Second Law of Thermodynamics here, but while it is useful for separating processes that happen spontaneously over time from those that do not, it is not infallible on what "over time" means. Its classical statement is that the entropy of a closed system can never decrease but, even if we could find a truly closed system that is not at equilibrium and attach to it a meter showing its entropy in multiples of Boltzmann's constant (neither of which are possible), the statistical nature of entropy would mean that the readings would not always increase in the direction of our intuitive arrow.

The third problem is quantum mechanics, a theory that is undoubtedly correct, fundamental to physics and yet does not make sense. While it is not usually seen as a time problem, the only freedom allowed by our scheme of physics to anyone wanting to resolve its philosophical difficulties without affecting its proven substance, is to try a different scale of time. Subsequent parts of this paper will show how this works.

Concluding Remarks

We all assume that time flows automatically, objectively, continuously, everywhere but, to be properly rigorous, these should be listed as the axioms of the logic system of physics, things that can be (and often are) taken for granted within it. All that physics actually tells us about time is that it is the last operationally-defined concept in its foundations. The operation that defines it is the act of counting, and any science can provide the repeating phenomenon, the unit that is counted to create a scale of time. The practice of physics obviously requires objective physical clocks, but this is a statement about the rules of physics not the nature of time. The drawback of physical clocks is that every tick is the same as every other; there is no sense of a future becoming something different, a past. It may not be a coincidence that the resulting laws of physics are static or reversible in time, and yet this threatens the whole enterprise since truth is revealed by experiments, not theory.

What to do, given that axioms cannot be questioned within the logic system they create? In our scheme the concepts of physics (volume, temperature, mass etc.) originated in our sense perceptions and became physical measurements only when they were given operational definitions. We then, quite rightly, favored the objective physical quantities over the subjective perceptions, and discovered great theories that explained their true nature and endowed them with natural units. But this process is now over; after the last great theory, quantum mechanics, physics is complete in the sense that there is only one such operationally-defined concept left, chosen by the BIPM to be time. The logical procedure in this one last instance is to quantify **both** the objective measure and the subjective perception. The former is ultimately Ptime. It is common, but wrong, for physicists to disparage the latter as "unscientific", apparently forgetting that there are many other sciences besides physics. Neuroscience is one that is entitled to its own scale of time, one that quantifies the "psychological" arrow of time.

The subjective perception involves the difference between the past and the future, which lies in what can be called its "knowability"; we can have definite information about events in the past but not those that have not yet happened. The relevant organ for this knowing is the brain which has a time scale called wtime that counts (in principle) the bits of information processed in the individual's brain. The tick of this scale is the individual's neurological time constant, τ, the average time it takes to process one bit. This number quantifies the fact that the amount we can learn about reality must be constrained by the power of our brains, but it also moves us out of objective physics and into a parallel logic system (physics+τ) that not only includes our limitations in dealing

with reality but does something utterly unexpected. Part 2 will show that this new system, with its new time axiom, not only explains why time flows in experiments, but reduces all the puzzles and paradoxes of quantum mechanics to common sense. In time-only physics it is hard to avoid the idea that the discontinuities that we experience as quanta must reflect discontinuities in time, and those of neurological Wtime prove to be just the right size.

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TIME AND THE QUANTUM
PART 2; WHENCE THE QUANTUM?

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Abstract

Part 1 established that the only freedom available to anyone wanting to resolve the philosophical difficulties of physics without affecting its proven substance is to consider different scales of time. The other natural unit of time besides the Planck time is the observer's neurological time constant, τ. Its human value puts it at the heart of quantum phenomena, between the minimum size of an atom and the rest energy of the electron. It also provides the tick of a personal, neurological time scale that is the source of its irreversible flow, and that is appropriate for our observations (as opposed to our theoretical descriptions) of reality. The philosophical problems arising from the quantum "act of observation" arise from the switch of time scales when an observation is made, and are resolved by adding this parameter to describe the observer. In the logic system of (physics+τ) the quantum becomes an epistemological phenomenon and all of the paradoxes of the subject are reduced to common sense. This logic provides a model not for how reality is, but for how a species of a certain brain power interacts with it and learns about it.

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Introduction

After a lifetime spent pondering the implications of quantum mechanics, Bohr (quoted in (1)) put the situation as follows;

It is wrong to think that the task of physics is to find out how nature *is*. Physics concerns only what we can say about nature.

That "we" implies a belief that our physics is somehow a specifically human activity, and part 1 of this paper described a scheme that justifies this belief without undermining the essential correctness of physics. It sees the subject as a system of logic, and the operationally-defined concepts on which it is based, mass, length, time etc., as its axioms, the truths accepted without proof on which it is based. Since these concepts originated in the human umwelt, the collection of senses and neurological pathways through which we interact with reality, their number is a measure of how far our physics is from the its goal of a universal, human-free description of reality. Physics made progress by attacking these axioms, each new great theory improving the system by removing one such concept from the list by explaining its true nature in terms of the presumably more fundamental ones that remained (thus providing it with natural units to replace the old arbitrary, operationally-defined ones). After the last great theory, quantum mechanics, there is only one such axiom left, one concept that can be and is taken for granted, time. Despite being endorsed by the International Bureau on Weights and Measures (henceforth known as the BIPM) this culminating time-only version of physics remains strangely unexplored, and provides the starting point for this paper.

As the last operationally-defined concept time is the only one entitled to multiple scales of measurement and arbitrary units. The operation that defines it is the act of counting, and the repeating phenomenon that is counted provides the unit of the necessarily discontinuous scale created by a particular clock. Physics is an internally consistent system of logic because it results from studying reality using physical clocks, and the one change allowed anyone seeking to resolve its philosophical difficulties without affecting its proven substance is to try clocks based on other fields. There are astronomical clocks and biological clocks, but the field most likely to limit "what we can say about nature" is neuroscience. The amount that any intelligent species can learn about reality must surely be constrained by the power of their brains. Given only the computational theory of mind, the idea that what brains do is to process 'information', this power can be quantified by the speed at which they do so, $1/\tau$ bits/s, where τ is the neurological time constant, the **average** time it takes to

process one bit. The ' . . ' are essential here to make the distinction between the objective information with which physics fills the world outside the brain, and this subjective neurological stuff that the brain processes to create the picture of reality that appears in its conscious part, what neuroscientist Richard Restek (2) calls our 'reality'. A personal neurological time scale can quantify what is called the "psychological" arrow of time, the kind that flies (relative to physical clock time) when we are having fun.

The value of this τ may vary considerably between individuals, but an order-of-magnitude estimate of the human value is available in many sources (2). The active elements in the brain are cells called neurons and there are somewhere between 10^{10} and 10^{11} of them. The critical fact is that each neuron sends out a bewildering array of fibers called dendrites that link up with those from as many as 10^4 other cells at junctions called synapses. The neurological correlate of the "bit of 'information' processed" is usually held to be the firing of one of these synapses. By electronic computer standards they are very slow, firing only 10^3 times a second, but since there are some 10^{15} of them this suggests a total processing rate of 10^{18} per second. This may, however, be an underestimate. Besides neurons brains contain another type of cell called glial cells that were once thought to play no role in the processing of 'information', but this may be wrong. Furthermore, the firing of a synapse is an extremely complex bio-electro-chemical event involving the transfer of one of several types of neurotransmitter molecules to a specific receptor on the other side. If a synaptic firing involving one neurotransmitter can send one message to the next neuron while a different neurotransmitter conveys a different message, and the glial cells really are doing something then our estimate of its information processing speed is closer to 10^{19} bits/s or a τ value somewhere between $10^{-19}$and 10^{-18}s. We might here pause to admire ourselves, since $1/\tau \approx 10^{19}$ bits/s is an astonishing processing rate, several orders of magnitude faster than our best supercomputers.

The central, astonishing result of this work is that, in time-only physics, this τ value of ours appears in the heart of quantum phenomena (3), the very region where Bohr's "what we can say about reality" becomes inherently uncertain. In our scheme the universal constants are reduced to conversion factors, so there can be a corresponding characteristic human length, $c\tau$, which is the size of atoms, and a characteristic human energy, h/τ, which (in the rough order-of-magnitude sense employed here) is close to that of the electron. It has long seemed clear that there must be a connection between the fact that reality comes in discrete chunks called quanta and that information comes in discrete bits. Wheeler described quanta as "atoms of information", and our solution

requires only changing that to 'information'. Quanta are here just a manifestation of the time it takes the observer's brain to process one bit.

The effect on physicists is to allow them to do what most do already, to ignore the philosophical difficulties and get on with their valuable work, perhaps chastened by the knowledge that what they are up against is not the complexity of reality *per se* but the limited ability of their finite brains to deal with that complexity. The solution to all those difficulties involving time and the quantum is to be found in another system of logic (physics+τ) located on the border with neuroscience, where time flows irreversibly in those quantum-sized ticks of τ, which is shown here to be a natural unit of time.

The Timeline

Time-only physics allows us to spread everything there is out along the single logarithmic scale shown in figure 1, from the Planck time $t_p=(Gh/c^5)^{1/2}=1.35\times10^{-43}$s, to the age of the universe, t_u=13.8 billion years or some 10^{17}s. Part 1 showed that t_p is the shortest increment of time that exists, Mother Nature's own unit of time, the only quantity with units of time that can be created from her universal constants. All times are strictly ptimes, purely conceptual counts of these units, but t_p is so small that the result is effectively continuous for all purposes short of quantum gravity. So while figure 1 could be normalized by t_p, thus eliminating those arbitrary human "seconds" and reducing it to a sequence of ptimes from 1 to $\approx10^{60}$, we will treat it as a continuous line while realizing that those "seconds" are strictly those of discontinuous Ptime=$t_p\times$ptime.

The timeline represents the culmination of our scheme of physics but it turns out to be a picture not of objective reality but the ultimate version of our 'reality', showing how we experience reality through the last vestiges of our umwelt. Our dominant sense perceptions (vision, feel, and time) and the operationally-defined concepts to which they give rise (length, energy and time itself) provide us with separate windows on reality, but here they also give a new perspective on the source of the quantum.

Everything we actually experience as time appears on the right side of the line, from the age of civilization at $\approx10^{11}$s to the human lifetime at $\approx10^{9}$s down to the shortest interval of which we are actually aware $\approx10^{-2}$s. The fact that most digital watches only register two decimal places of a second is a restriction imposed not by watchmakers but by our brains. Below this point our umwelt cannot experience reality as time, so it switches to a different concept, length. One of the many strange but unremarked facts thrown up by the timeline is

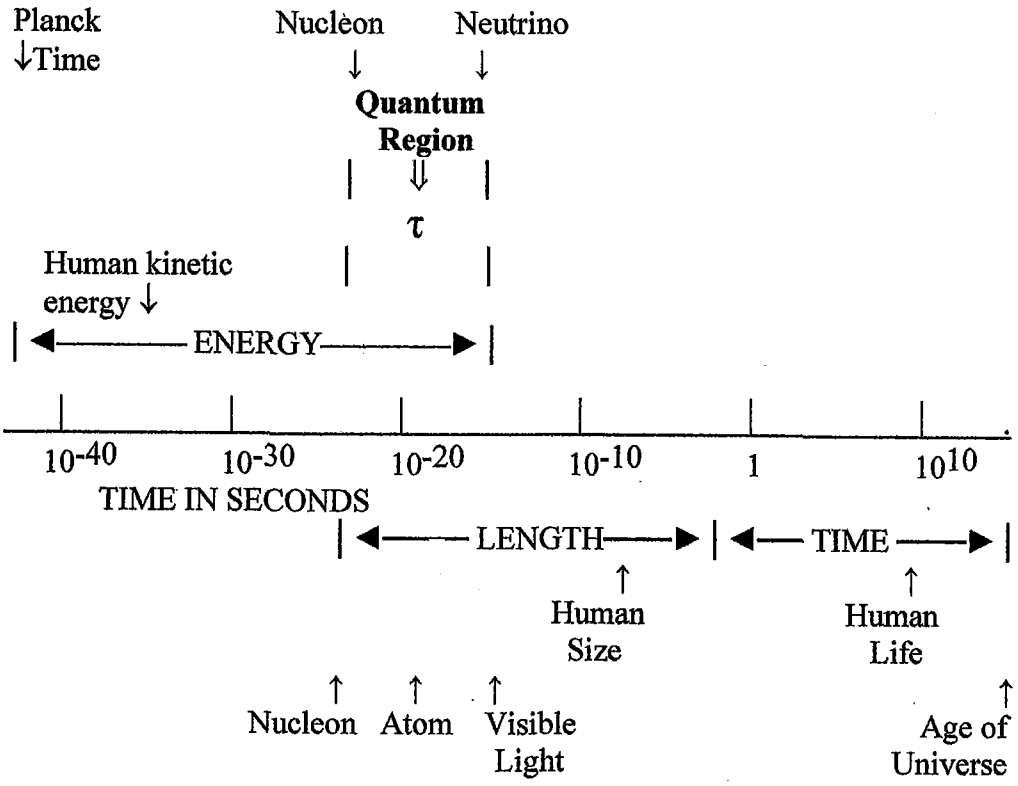

FIGURE 1: EVERYTHING ON A TIMELINE

that, as a length, this $t_l (=l/c) \approx 10^{-2}$s is within an order of magnitude of the size of the planet on which we evolved! This is a very convenient fact because it allows the BIPM to synchronize suitably-equipped watches by sending out radio signals to mark midnight without worrying about the time lag involved in the transmission to distant parts. It might be argued that the LENGTH section should extend all the way out to the end of the timeline, since t_u is (in our order-of-magnitude sense) also the radius of the universe (which will here always mean the observable universe). However, even non-scientists are happy to express such astronomical distances in time units, light years, particularly after hearing

the time lag for themselves during the moon landings. But they do not extend the idea to terrestrial distances, which are always expressed in units of length.

The length-as-time ($t_l=l/c$) section of the timeline stretches down past the size of the human body at $t_l\approx10^{-8}$s to the smallest thing we can see unaided, $t_l\approx 10^{-13}$s, down to the smallest things we can see even with an optical microscope, bacteria at $t_l\approx10^{-15}$s. This should be the end of the line, since the concept of length must have originated in our ancestors' sense of vision, and we have reached its limit, the wavelength of visible light. Furthermore, while our official unit of time is a certain tick of the cesium atom at $t_c\approx10^{-10}$s, some clever makers of atomic clocks have managed to subdivide this into units closer to 10^{-15}s, making this the smallest time (and thus distance) that can actually be measured. So, according to our umwelt and the rule that science deals in measurable quantities, the concept of length ends here. But physics has pressed on, extending the line into what, for reasons that will become apparent, is labelled the Quantum Region.

The smallest things that can be "seen" with our most exotic electron microscopes are atoms at $t_l\approx10^{-18}$s, but physics has gone even further, down to the smallest thing to which it usually attaches a size, the nucleon at some 10^{-15}m or $t_l\approx3\times10^{-24}$s. This end of the LENGTH line is also defined by the wavelength of the high-energy gamma waves that mark the rather mysterious end of the electromagnetic spectrum. The obvious question is whether there are lengths shorter than this, but the question is misplaced. Length is not an idea in the mind of God but in that of humans. The timeline represents our time-only version of reality, but length is just how we experience a section of it, from the size of our planet to the smallest things we can see. Our microscope technology extended the idea down to the size of nucleons (Rutherford's classic experiment that first established their existence by shooting alpha particles through gold foil might be described as a transmission proton microscope) but beyond here the concept is not just unobservable but even incomprehensible to human minds.

Physics shows that our interaction with reality switches here to another different concept, ENERGY. The nucleon is a proper marker for this switch because its rest-energy-as-time $t_e(=h/E)=4.4\times10^{-24}$ s is very similar to its t_l value. Physicists even discuss those gamma waves in terms of an equivalent photon energy despite knowing this is not strictly correct (photons have no rest energy but, since they are always moving at the speed of light, their relativistic energy is $0\times\infty$, which is actually indeterminate). Energy being inversely related to time, moving further left along this line means increasing energy, from the rest energies of all the atoms ($t_e\approx10^{-24}$ to 10^{-26}s) to the Higgs boson at $\approx10^{-27}$s, and the ever more massive particles with which theories of particle physics dot the

line, but which are beyond the reach of human experiments. Everyday life provides more familiar energies, from our kinetic energy when out walking ($t_e \approx 10^{-37}$s) to that in a gallon of gasoline ($t_e \approx 10^{-40}$s). In terms of our umwelt energy is not something we see but something we feel, usually as heat. The kinetic energy of a single molecule at room temperature is $t_e = h/kT \approx 10^{-13}$s where k is Boltzmann's constant, but our skin cannot detect this. It is the effect of zillions of such impacts that creates the comfortable blur of "room temperature", the energy that humans need to prevent us from freezing to death, and this combined effect would appear firmly on the ENERGY section of figure 1. The end of the line at t_p corresponds to the Planck energy of around a ton of TNT, certainly the largest burst that a human would want to be around.

Part 1 showed that ENERGY transitions here into yet another concept, MASS, the Planck mass of 0.055mg (roughly that of a 0.3 mm sand grain) being the lightest object that our skin can detect. For bigger objects the output of our umwelt might better be described as "touch" rather than "feel". Mass could be included in figure 1 by adding another line for the mass-as-time $t_m = mG/c^3$, and another strange unremarked fact is that, in the order-of-magnitude sense that prevails throughout this work, this t_m line would be the same length. It would start at the Planck time where mass takes over from energy, and end at the mass of the universe which is estimated at 10^{51}kg or $t_m \approx 10^{17}$. The end of the time-only physics line thus marks not just the age and size of the universe but also its mass!

The Quantum Region

When the physicist moves back rightwards along the ENERGY line in figure 1, they do not stop at those nucleons but press on into the Quantum Region. Here the line is populated by all kinds of subatomic particles from the electron at $t_e = 8.09 \times 10^{-20}$s down to the lightest particles known to have a rest energy, the neutrinos whose few electron volts translate to $t_e \approx 10^{-15}$s. Yet another strange but unremarked fact is that this is the very point on the timeline where length becomes a perceptible and measurable concept. Length can therefore take over our dealings with reality here, in much the same way that energy took over from it in the previous section.

The effect is to create what is labelled on the timeline as the Quantum Region, the stretch from roughly 10^{-24}s to 10^{-15}s that contains the lengths and rest energies all of our familiar quantum waves and particles. This region here starts to look like a gap in our umwelt, the parts of reality that are too small to see but too light to feel. As Capra says (4) "Probing inside the atom and investigating its structure, science transcended the limits of our sensory

imagination". Although our sense perceptions do not work in this region, physics dealt with it logically enough by extrapolating the concepts derived from these perceptions, length and energy, from the familiar macroscopic world into this mysterious sub-atomic one.

This Quantum Region is thus where our concepts of energy and length overlap, which gives a new perspective on its peculiar features. A macroscopic object like that sand grain can be defined as one that has **both** a rest energy, t_e, well to the left of the Quantum Region, **and** a size (here $t_\ell \approx 10^{-12}$ s) well to the right. But physics tells us that a piece of quantumstuff can only have a rest energy, as a particle, **or** a length, as a wave, but not both at once. Quite so, for in time-only physics it can only occupy one spot on the timeline, which requires $t_e = t_\ell$, which can be recognized as De Broglie's equation, t_ℓ here being the length of the wave corresponding to the rest energy of the particle. A particle can, of course, only behave as a wave if this wavelength is longer than its physical size. It is not a coincidence that the left boundary of the Quantum Region is fixed by the nucleon, a particle for which the two numbers are similar, or that many quantum particles, like the electron, are free to be wavy because they have no physical size at all. That sand grain, like all macroscopic objects, cannot exhibit wave-like quantum behavior because its wavelength is vastly smaller than its physical size.

While this interpretation makes sense intuitively there are several objections, the first being that it does not do justice to what physics has actually achieved. The goal of the subject was to remove all traces of the human umwelt, although in our scheme there will always be one left, time. The last two great theories, Maxwell's equations and quantum mechanics, should have eliminated length and energy, rendering them superfluous, yet they are still there in the above description. This particularly affects quantum mechanics; the wave-particle duality was described above as a duality between our concepts of length, the defining characteristic of a wave, and energy, that of a particle. If these are no longer fundamental concepts what becomes of the quantum? Our time-only version of physics must have a time-only interpretation.

Enter the Observer

Why is the Quantum Region where it is on the timeline? The physicist might say that it is because Planck's constant has the value that it does, but our scheme has already transcended such simplicity. Planck's constant has the value 6.625×10^{-34} kg m^2/s only because human beings decided that kilograms, meters and seconds are suitably sized units for their operationally-defined concepts of

mass, length and time. Or the physicist might say that the location of quanta is simply a fact about reality; there is no "why". But in the logic of (physics+τ), not only does the question exist but the answer is obvious from figure 1. Since it includes all times, our neurological time constant, $\tau \approx 10^{-19}$s, must appear somewhere on the line, and our hypothesis that this τ value must constrain our knowledge suggests that it must be somewhere significant. And there it is at the heart of the Quantum Region, the region where our knowledge of reality becomes inherently uncertain and probabilistic. This suggests an entirely new interpretation of the quantum, one that is not admissible in objective (i.e. τ free) physics but makes perfect sense in the logic of (physics+τ). Our all-too-finite brains are simply not entitled to a complete and objective picture of reality, and our inherently uncertain knowledge of quantum phenomena is just the first symptom of this limitation.

This new interpretation provides a graphic illustration of how quantum mechanics resulted from the physicists' strategy of reductionism. As they studied ever smaller chunks of reality they were moving leftwards from the right side of figure 1, but as they studied ever lighter particles they were moving rightwards from the left side. After passing the wavelength of visible light in one direction and the rest energy of atoms in the other, they hit the neurological limit represented by τ but, since they were equipped neither to recognize nor to deal with it, they overshot it by a few orders of magnitude in both directions. Hence the Quantum Region and a theory that is scientifically correct but philosophically confusing.

The problem was seen above as confusion between our concepts of energy and length caused by the limitations of our umwelt, so the obvious solution is to strip away the overlap of concepts, and refer to everything to the left of τ as energy and everything to its right as length. This reduces the essence of the timeline to a time-only inequality:

$$t_p \leq t_e \leq \tau \leq t_l \leq t_u \qquad (2.1)$$

To see the importance of this equation, recall the jogger's lesson from part 1 that what separates frequency-like phenomena from time-like ones in our world of discontinuous time is the unit of the prevailing time scale. In equation (2.1) what separates our naturally frequency-like concept, energy, from our naturally time-like one, length, is τ. It follows that τ is the second natural unit of time revealed by time-only physics. It is the shortest interval of time our brains can deal with, that required to process a single bit of 'information'. While the

Planck time, t_p, is the natural unit of reality and the theories that describe it, τ is the natural unit for how our brains learn about that reality. The fact that it is no less than 24 orders of magnitude larger than t_p makes the ability of our physics to understand 5% of the matter in the universe look pretty good. But what is the time scale of which τ is the unit, and when is this scale appropriate?

Wtime

All science begins and ends with observations of reality, and what is important for our purposes is that these observations are not physical acts but neurological ones, acquisitions of 'information' about reality by the observer's brain. Neuroscience is a perfectly respectable science that is entitled to a time scale of its own, and the appropriate scale is a count of the bits of 'information' processed by the brain, a personal scale to be called wtime. This is not directly measurable, but then neither is ptime.

Any device that processes information can claim such a wtime scale. Our digital computers process information sequentially, taking the same Ptime, their time constant τ_c, over each bit. For a lap-top τ_c even has a similar magnitude to the vibration of the cesium atom, $\approx 10^{-10}$s, thus making lap-top time almost the same as the cesium atom time that we accept as the real thing. Our brains, however, do not work like this, synapses firing off all over the place at irregular Ptime intervals, but the only change this requires was already made when τ was defined as the **average** Ptime between bits. It makes sense to take the average over that shortest interval of which we are aware, some 10^{-2}s. Since $\tau \approx 10^{-19}$s, in this interval the brain processes the enormous number of 10^{17} bits, which explains why reality usually appears continuous to us despite the discrete nature of 'information'. It is also more than enough to average out random variations in the Ptime between bits, so that a Wtime scale defined as one that ticks forward by one increment of τ whenever a bit is processed will usually (but not always) be the same as Ptime. The main difference is that the smallest time it can measure is not the t_p at the end of figure 1 but the τ nearly half way along it (it is not a coincidence that we experience the part of the timeline between these points not as a time but as the frequency-like concept of energy). Since τ was shown above to be a natural unit of time, this Wtime=$\tau \times$wtime must be a natural scale, the proper scale not for objective descriptions of reality but for the observations that validate those descriptions. It gives a new perspective on several issues.

Among the best evidence for multiple scales of time is that we all know intuitively what "the rate of passage of time" means, despite the fact that while we only had one scale the phrase was meaningless. If time were continuous it's

"rate of passage" would be written dt/dt, which is 1 by definition. Only now that we have two, natural, discontinuous scales can it have the meaning of how fast one of them, Wtime, goes relative to the other, Ptime. While our brains hum along at their average rate of $1/\tau$ bits/s the relationship between them is a constant, which is why we can all agree what time it is despite our differing values of τ. But while we sleep our brains slow down and we "lose track" of time. When we are busy they must speed up, and a processing rate $>1/\tau$ makes Wtime go faster than Ptime. We say that time flies when we are having fun but, if time were just the reading of our physical clocks this would also be meaningless. They would be speeding up relative to what?

A question that has worried physicists from Einstein to Mueller (6) is what NOW means. If time were continuous NOW would be an infinitesimal and the question would certainly be unanswerable. Making it discontinuous makes NOW finite but part 1 pointed out the problem that every tick of a physical clock is the same as every other, making no distinction between a past, present and future. Wtime is very different. Here counting proceeds in a series of NOW's, each lasting for a quantum-sized increment of τ and uniquely defined by the bit of 'information' processed within it, a bit that that can be added to the store of knowledge in the memory. When I observe an event like a coin toss, the event itself moves from the uncertain future into the known (at least by me) past when the bit (actually bits) of 'information' about its outcome, *heads/tails*, appear in my brain. Furthermore, the unstoppable (except by my death) activity of my brain creates, in principle, my wtime past, a huge sequential list of all the 'information' my brain has ever processed. Some of these bits arise from internal cogitation, some from control of internal processes like digestion, but some (perhaps most) arise from dealing with the information flooding in unceasingly through my senses about what is going on around me. Encoded in this list is everything I have ever experienced, everything I can possibly know (including the stuff I have forgotten), every emotion I have ever felt and every face I recognize: in some sense this list defines **me**. It is the interface between the subjective me and objective reality, between neuroscience and physics. Time passes as this wtime past gets bigger, which is the right direction for time.

The conclusion must be that Wtime quantifies our sense perception of the passage of time. It embodies, at least at a personal level, all the essential features of time that are missing from the fundamental laws of physics, a potentially knowable past, a well-defined but ever-moving present, and a future about which I can have no definite 'information'. Physicists know about this of course; they call it the "psychological" arrow of time, but the rules of their profession require them to favor the objective thermodynamic arrow despite

being painfully aware of its drawbacks (5,6). The idea that the passage of time is the observer's contribution to the act of observation demands at least one parameter to describe the observer. Since this parameter, τ, implies that the reach of human physics is limited by the power of the human brain, it might not be popular with physicists. But in its proper place, the parallel logic system of (physics+τ), Wtime provides a natural, irreversible scale of time that governs **observations** of reality, one whose discontinuities are, crucially, the size of quanta. Hence the ability of this logic system to resolve the philosophical difficulties of quantum mechanics without affecting the substance of the theory.

Experiments and Quantum Observations

Our waking hours consist of a vast series of subconscious observations of what is going on around us. Information about our surroundings floods in through all our senses, becoming the 'information' that our brains process into the astonishing 3-D movie that appears in its conscious part, our personal 'reality'. This is what our brains have evolved to do, help us to survive by taking advantage of the opportunities in our environment and avoiding the dangers. These acquisitions of 'information' about how reality works form the basis for our knowledge of the world, and scientific experiments are just well-controlled examples of the genre. They necessarily involve an experimenter and work in their Wtime. They have a beginning and an end, and the difference between them is the presence in the experimenter's brain of the 'information' about reality the experiment was designed to reveal. That is why we do them. The laws of physics may be reversible in time, but the idea of doing an experiment backwards, starting with the 'information' it reveals and going to a lot of trouble to destroy is, is simply absurd.

The greatest disparity between theory and experiment in all of science is that time flows in its familiar irreversible fashion in all experiments, despite appearing to be static or reversible in the fundamental laws of physics. This causes much anguish; all scientists know that they must believe the experiments over the theory, but the flow of time seems to fall just outside physics. The logic of (physics+τ) provides immediate relief. Here the laws are descriptions of reality that must work in objective but directionless Ptime, while experiments are observations of reality that work in the experimenter's subjective but irreversible Wtime.

Why do we not notice the switch when making an observation? The macroscopic world floods our brains with so much information that Wtime is essentially continuous and thus indistinguishable (except for its irreversibility)

from Ptime. But as we examine reality at ever smaller scales the amount of information on offer must decrease. In the time-only physics of figure 1 quanta occupy the region around τ where the discontinuity of Wtime must become significant. Here the simple observation becomes the philosophically traumatic "collapse of the wave function", but what actually collapses is the level of intelligence being applied. The theory works in increments of Mother Nature's own Planck time, but the act of observation in those of the observer's vastly slower brain. It is not a coincidence that quantum observations often yield only a single bit of information, *spin up/down, atom intact/decayed* etc.

Penrose (7) gives a formal proof of much of this. He shows that the development of the wave function according to Schrodinger's equation (what he calls the U process) is as symmetric in time as any other theory, but that the act of observation that collapses this function (what he calls the R process) is asymmetric. This can now be seen as a particular example of our general hypothesis that, while theory is objective and works in reversible Ptime, observations require an observer and work in their irreversible Wtime. It is a fact that could only become apparent when physics reached the scale at which the discontinuity of Wtime becomes significant.

With the benefit of hindsight, much of this seems obvious. The untried solution to the problems of the quantum "act of observation" is to introduce a parameter to describe the observer. This τ must be, in some sense, the smallest chunk of space-time the brain can deal with, the smallest increment from which it can acquire a bit of 'information'. As a length it is the size of atoms, so anyone studying reality at the sub-atomic level **must** find their knowledge to be incomplete because they are trying to deal with a fraction of a bit, and this is exactly what happened. It has always seemed clear that the fact that reality comes in discrete chunks called quanta must be connected to the fact that information comes in discrete bits, but physics has never quite pinned down the connection. (Physics+τ) can do so because what matters is actually 'information' and the time, τ, needed to process one bit.

Probabilities

Suppose that the τ-sized region of space I am observing contains the original quantum entity, an unstable atom. According to the theory of quantum mechanics, if the atom is observed continuously it will never decay (8), but this Quantum Zeno Paradox is widely ignored because it violates the experimental truth that the decay must eventually happen. But when it does so it seems like a random event, an effect without a cause, a case of God playing dice. The best

that physics can do to predict when it will happen is to study a macroscopic (i.e. $>>\tau$) chunk of the element that contains many identical atoms, and calculate from their decay the natural unit of time for this process, the atom's half-life. But all that can be calculated from this is the **probability** that a single atom will decay in a given interval.

Now reconsider this simplest of quantum experiments in the logic of (physics+τ). The Quantum Zeno Paradox vanishes because the Wtime that governs observations is itself discontinuous. It ticks along in increments of τ during each of which my brain can handle only a single bit of 'information', atom *intact/decayed.* When the answer suddenly becomes *decayed* it still seems like a random event, but the probability now has a different explanation. $\tau \approx 10^{-19}$ s may seem a vanishingly small increment to me but it is an eternity to Mother Nature who, working on the Planck time, can make all kinds of things happen in that time in a chunk of reality the size of an atom. Unfortunately, human brains are simply too slow to know what these things are, never mind ordering them into the proper sequence of causes and effects. My brain can only handle the one bit, the end result. Only if I were replaced by a visiting alien whose τ value were, say, a million times smaller than mine, would their more sophisticated physics resolve the conundrum by seeing deeper into the atom and explaining exactly why it decayed when it did.

This explanation extends, in outline, to all of quantum mechanics. All our observations of space-time happen in Wtime, which means that they can yield only statistical knowledge about sub-τ scales of reality. But theory exists to explain observations. In what is surely the greatest intellectual accomplishment in history, the founders of quantum mechanics developed an objective (i.e. works in Ptime) theory that can predict the probabilities of events far more complex than our single atom. However, since they did not understand that what they were up against was not so much the complexity of reality *per se* as the ability of their finite brains to deal with that complexity, they had to ascribe those probabilities to reality itself. It is not surprising that the result, while correct, is philosophically confusing.

A complicating factor in all discussions of quantum mechanics is that the concept of probability itself has several possible interpretations. It appears here in its Bayesian sense. Von Baeyer (9) describes such probabilities as "subjective, a measure of degree of belief". This is problematical within the objective logic of physics but (physics+τ) provides the essential elements that physics cannot, a subject who has the belief and a measure of the brain power that determines how right their belief is likely to be.

Matrix Mechanics and Wave Mechanics

The founders of quantum mechanics actually produced not one but two complete versions of the subject, Heisenberg's matrix mechanics and Schrodinger's wave mechanics. Once they were shown to be mathematically equivalent the philosophical differences between them were usually ignored, but they re-emerge here. Heisenberg's version is simpler, more sparse, and would thus be favored by application of Occam's Razor. In particular its equations do without that "t" whose interpretation is the issue here. It has only two times, the beginning and the end of an experiment, what happens in between being, in Heisenberg's view, beyond our powers to know. Significantly, both these times have the nature of Wtimes, being defined by the 'information' available to the experimenter at that instant. She knows the initial condition of the system because she set it up, and she knows the final state because she makes the observation that ends the experiment.

In the logic of (physics+τ) the time between these two instants passes as the experimenter's Wtime, a vast number of τ increments each defined by the bit of 'information' her brain processes in that instant. Some of this will be just thinking, but those who make their living by abstract thought naturally tend to over-estimate the fraction of the brain's activity that is devoted to it. Some will be concerned with maintaining her body's autonomous functions such as digestion, but most with the unstoppable flow of information coming in from her senses and the proper responses to it (stay upright, mind that table etc.). Others will arise from the things that her brain makes her do to fill in the time, writing up notes, cogitating, doodling, chatting to colleagues and making coffee. According to the rules of quantum mechanics the one thing she cannot do is to look at the experiment, for the resulting 'information' would bring it to a premature end.

While Heisenberg's is the Wtime approach, most physicists prefer Schrodinger's approach because it embodies their view of that "t" as something that passes automatically, objectively and continuously. The wave equation is what they expect a law of physics to be, a differential equation describing how something, a wave function in this case, develops over time. However, the wave function is not a thing, only a mathematical representation of the probabilities of things, and the great mystery in this approach is how a simple observation magically replaces these probabilities with "real" things like waves or particles.

Schrodinger's Cat

When Born showed that the wave function was not actually a thing but only a mathematical statement about the probabilities of things Schrodinger was appalled, and he invented his famous thought experiment to highlight the absurdity by amplifying it from the quantum to the macroscopic level. There is a box containing a cat, a vial of poison gas, an unstable atom, and a mechanism arranged so that if the atom decays the vial is broken and the cat dies. The question to be answered is "What exists in the box when no one is looking?". The obvious answer is "A cat, either alive or dead", but the conventional interpretation of quantum mechanics does not allow such common sense. It insists that the unobserved atom consists of a linear superposition of intact and decayed states and that the cat is therefore both somewhat alive and somewhat dead, not a tenable state for any creature.

The generations since Schrodinger have worried over the first part of the question "What exists in the box?". Perhaps their agonizing has not been fruitful because the answer lies in the second part, the idea of a time "when no-one is looking". The hypothesis of (physics+τ) that Wtime is the source of the passage of time provides a solution because everyone's Wtime is full of 'information'. My Wtime present, my "now", is a personal concept that lasts a time τ and is uniquely defined by the bit of 'information' my brain is processing at this instant. When I look in the box there is a bit of 'information', *cat alive/dead*, processed in my brain and a corresponding NOW in my Wtime. When you do the same, there is a corresponding present in your flow of Wtime. When anyone looks in the box there is a Wtime NOW corresponding to that bit of 'information', but what about when no-one is doing it? There simply is no such Wtime as "when no-one is looking". In (physics+τ) the cat paradox vanishes because it is based on a non-question.

The great appeal of this solution (like most of what is said here) is that it is general, requiring no special pleading for the quantum case. The question can always be asked in the future tense "Will the cat be alive the next time it is examined?", and the answer can then only be a probability because the future is always uncertain. The only difference between the cases is how the probability is determined. In Schrodinger's case it must be calculated from quantum theory, while for a cat in a box without all the added paraphernalia it would be estimated from the age of the cat, whether the box is airtight etc. The question can also be asked in the past tense "Was the cat alive the last time it was examined?", and the answer will then be a definite bit of 'information' obtainable by asking the person who looked. The past is the realm of such information. The error made by physicists is to ask the question in the present tense even though their logic

system provides no definition of "the present". The logic of (physics+τ) provides such a definition, and thus limits the use of the present tense.

The Two-Slit Experiment

Feynman believed that all the weirdness of the quantum world is encompassed by the two-slit experiment, so the next step must be to re-examine its strange results in (physics+τ). A stream of electrons, or any other quantumstuff, is sent towards a barrier in which there are two narrow slits. When both slits are open, an interference pattern appears on a screen placed behind the barrier, a result that is readily explicable from the wave manifestation of quantumstuff. But if slit 2 is closed all that appears on the screen is the expected bright line produced by the particles passing through slit 1. What is astonishing is that the same patterns build up on the screen over time if the electrons are sent through the equipment one at a time. This means that electrons passing through slit 1 do one thing, go straight on if slit 2 is closed, and something altogether different, spread out to form an interference pattern, if slit 2 is open. So how do those electrons passing through slit 1 know the state of slit 2?

This is a silly question. Electrons cannot know anything, only our brains can, which brings us to the interaction with the observer described here. All that need be added in order to explain the result is a simple principle of causality: the future must be consistent with the present, but the present is now the definite personal Wtime NOW rather than the abstract Ptime version. When slit 2 is closed there is 'information' in the observer's brain about how each electron got through the barrier, *slit 1*, and this bit of 'information' serves to define a Wtime present. In order for the future to be consistent with this present the electron must hit the screen behind slit 1, and this is true for all electrons as long as slit 2 is closed. But when both slits are open the observer cannot know which slit any individual electron went through. There is no such 'information' in his brain, no such present in his Wtime, and so the electrons are free to do whatever they want, which is apparently to form an interference pattern. Only if there is no bit of 'information' "particle came this way", and no corresponding Wtime NOW, is the future unconstrained and the quantumstuff free to behave like a wave.

However strange this explanation may sound it is consistent with what has been said so far and it passes the ultimate test by correctly predicting the result of a bizarre extension of the experiment, one in which both slits are open but the participant still knows where each electron goes. When a detector is placed over one slit to register whether or not the electron passed through it, the interference pattern disappears to be replaced by a bright line behind each slit.

Why?: because the detector once again creates that critical bit of 'information' in the observer's brain, *slit 1 or slit 2*, which constitutes a Wtime present. Once again, everything that happens after that present must be consistent with the information that defines it.

Causality (like probability) is too big a subject to be explored in depth here but the arrow of time must be fundamental, since the one certain difference between causes and effects is that the former must happen before the latter. Changing the source of this arrow from an assumption about reality (physics' position) to a consequence of the observer's neurological activity (the (physics+τ) position) seems to imply that only observed events qualify as causes. This is not as odd as it sounds, at least for science, for where does the scientist search for the causal connections that provide their subject matter if not in the array of information that constitutes the sum total of humanity's observed past. Unobserved events, although vastly more numerous, can obviously not appear as either causes or effects since they never registered in the minds of scientists.

Conclusions

In the 19th century mathematicians dared to change one of the "obvious" axioms of Euclidean geometry, the parallel postulate, thus creating the broader perspective of the non-Euclidean geometries (and ultimately the general theory of relativity) without affecting the validity of the original version. The finding from part 1 that time is discontinuous and must be allowed different scales of measurement allows a similar procedure here. The time-only culmination of physics is a logic system with unstated axioms, creating the confusion described most dramatically by Weyl (quoted in 10);

The objective world simply **is**, it does not **happen.** Only to the gaze of my consciousness, crawling along the lifeline of my body, does a section of the world come to life as a fleeting image in space which changes continuously (?) in time.

No matter how obvious physics' axiom, the unit of its time scale, may seem, it can be changed to create a new system of logic (physics+τ) in which "the gaze of my consciousness" is the source of the passage of time that makes "the world come to life". It provides a broader perspective on our experience of reality, one in which individual Wtime is the source of the irreversible flow of time and its τ-sized discontinuities are the source of the quantum. But this makes no difference to the substance, as opposed to the interpretation, of physics.

In this new logic figure 1 appears as a map of our **human** physics that incorporates the constraints imposed by the finite power of our brains. Things on the right side happen slower than our brains work, can be expressed as Wtimes (i.e. multiples of τ), and should therefore be well understood. Progress in physics has involved studying phenomena that were ever smaller, faster and more energetic, all of which correspond to moving from right to left along the line. Among the evidence for those human neurological limitations is the tendency for our technologies to pile up around the right boundary of the Quantum Region. Our fastest communication, for example, has gone from radio waves to visible light in optical fibers. Here too are the tick of our best clocks and the time constant of our fastest supercomputers, further progress in both cases being inhibited by the consequences of moving into the Quantum Region. Kurzweil (11) simply assumed that the huge increases in computer speeds over the last few decades would continue, and speculated about the consequences of having computers that work as fast as the human brain. It now seems that this is achievable (if at all: this is a great unasked question at the heart of Artificial Intelligence) not by hooking together tens of thousands of our conventional devices, but something entirely new called a quantum computer. The connections between information processing, quanta, and the human brain seem to be inescapable.

Just inside the Quantum Region is the realm of nanotechnology, where quantum effects start to become significant. Further along is that of "high energy" physics, but the energy is "high" compared to what if not the characteristic human energy (h/τ)? The current proven limit of the subject is the Higgs boson, whose rest energy puts it some 7 orders of magnitude to the left of this point. Is it a coincidence that the most powerful and expensive experimental equipment humans are ever likely to build, the Large Hadron Collider at CERN, must repeat the basic experiment of smashing two protons together tens of millions of times in order to detect one such boson?

Theorists populate the line beyond this point with many more massive particles, down to the magnetic monopole near the Planck limit, but they are beyond the reach of experiments that can actually be performed by humans. Why should this be so? Because the τ parameter that describes human limitations enters the picture only through the Wtime scale that governs experiments. The theorists may object, quite rightly, that their work involves considerable neurological activity, but the key fact is that the speed of their 'information' processing has no necessary relationship with that of the process being described. They can spend weeks formulating the equations for a process that lasts only attoseconds and will happily allow their computer a few minutes to

solve them. Experiments, on the other hand, work in what computer programmers call "real time": anyone who wants to observe an attosecond process needs an instrument that works this fast, and this is close to the limit of the human brain, the tick of Wtime.

At this end of the line times cannot be quantified as Wtimes because they are $<\tau$; we experience them as the frequencies we call energy. Things here happen much faster than our brains can deal with, providing a natural home for all the "dark" (i.e. undetectable by humans) matter and energy that make up most of the universe. Is there hope for progress in this direction beyond waiting for those hypothetical aliens to show up with τ values millions of times smaller than ours and thus much closer to a Theory of Everything? Selecting hundreds of our best brains and having them collaborate can create an effective τ value much smaller than any individuals', which is a good description of CERN. But another potential benefit of (physics+τ) is that, since τ appears as a variable, putting in the τ values of those aliens might give us some idea how they experience the universe. What, for example, would the ultimate observer, one whose τ is the Planck time, make of black holes?

Concluding Remarks

Penrose (7) and others have suggested that the philosophical difficulties of the quantum might be resolved by finding that our brain function depends in some way on quantum mechanical operations. This has not proved fruitful because the connection between our brains and the quantum is the neurological time constant τ, the intermediary being the nature of time.

It is not surprising that physicists find that their quantum mysteries are centered on the "act of observation". The goal of physics is a complete and objective picture of reality, but observations cannot be objective because they necessarily involve an observer. With the benefit of hindsight, the obvious solution is to incorporate a parameter to describe this individual, and this is τ. The biggest mystery in most physics' interpretations of the quantum is that this act of observation seems to **create** the waves or particles that are observed, out of nothing more than substantial than a wave function. In (physics+τ) all it creates is the bit of 'information' it generates and the NOW, the increment of time in which it happens. Our lives cannot be objective either, they consist of an endless series of such observations of our surroundings, and part 3 of this paper will show this to be the source of Heisenberg's Uncertainty Principle.

Why has this solution not been found by the many fine physicists who have pondered the problems over the past century? They lacked the clues from

part 1 that all the basic concepts of physics are now defined in terms of time, implying that the answer must lie in different scales of time based on natural units. The finding that the human τ value is the same order of magnitude as quantum phenomena, while serendipitous, was always there to be made. There is perhaps a rule that the greater the physicist the less likely they are to step outside the objective rules of their profession, and the finer the mind the less likely it is to acknowledge its own limitations. Hawking (among others) points out that the processing of information, be it in a computer or a brain, must consume energy and generate entropy. He thus subordinates the "psychological" arrow of time to the thermodynamic one, but the argument does not prove this conclusion, only that the two arrows are likely to point in the same direction. What of Einstein? He would surely be gladdened by the fact that God no longer needs to play dice, but saddened by the realization of how far human brains are from that objective picture of reality.

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NEW THERMODYNAMICS: QUESTIONING TEMPERATURE IN OPEN SYSTEMS, e.g., IN ATMOSPHERIC PHYSICS

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Abstract

Lucidity is obtained by understanding the differences between kinematic and radiative heat transfer and their relationships to temperature. Differences become apparent when one evaluates the utilitarian temperature associated with closed systems and compares that to temperatures measured in open systems. Acceptance, requires the realization that the sciences founded upon closed system experimentation is not always ideal for formulating open system physics. Temperatures measured in open systems that are dominated by anisotropic radiation often become non-sensible, e.g., those in Earth's upper atmosphere.

Keywords: Inelastic collisions, Kinematic, Radiation, Temperature, Atmospheric Physics

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1. Introduction

This author has challenged traditional thermodynamics. Accordingly, self-referencing is necessary in order to highlight the previous conclusions that enlighten questions such as temperature in open systems, and especially those measured in vacuums. Admittingly, I used to claim that if a thermometer measures a temperature in any vacuum, then that vacuum has a temperature. New realizations have altered this claim. [1]

Gaseous temperature relations such as the ideal gas law, and kinetic theory are founded upon closed system experimentation. This author's improved kinetic theory realizes that a closed system's structured, vibrating wall molecules impose their energetics upon their enclosed gas molecules, and is a superior fit to known empirical findings [2,3]. Unlike traditional theory, it allows for inelastic collisions.

Elastic collision theorization enables one to utilize the truncated Hamiltonian and Lagrangian mechanics [4]. Truncated becomes the act of limiting the mathematical description of the thermal energy contained in a closed system to the system's gas' kinematics. This has emboldened the belief that Boltzmann's statistical thermodynamics has some universal applicability. Realizing that intramolecular and intermolecular collisions are inelastic, limits the approximations of such mathematics to sufficiently-dilute closed systems, where the illusion of elastic collisions exists [4-7], e.g., engines and devices.

Conservation of energy means that inelastic molecular collisions result in the creation of photons/phonons. An ensemble of such collisions results in a spectrum, e.g., a blackbody spectrum [1,5-7]. Blackbody spectrums witnessed in phenomena from enclosed vacuums to the stars, can now be better explained [1]. Note that misconceptions based upon elastic-collision science is not limited to blackbody radiation [8].

The illusion of elastic collisions exists because the walls of closed experimental systems recycle the system's thermal energy. This includes both the system's kinematic energy and radiative energy [4,5]. For example, the walls recycle radiation energy back into the system by a combination of reflection, and the absorption followed by the radiating back into the system. The walls recycle kinematic energy by absorbing that energy and imposing its kinematics back onto the gas molecules. Thus, fulfilling the requirements of the illusion. Something that has gone unnoticed by the casual observer for far too long.

In gaseous systems, blackbody radiation is dispersed between the molecules. In general, the total energy associated with radiation is minute in comparison to the system's kinematic energy. Thus, a system's energy can often be estimated in terms of elastic collisions, i.e., all of the system's energy being described in terms of the gas molecule's translational, rotational plus vibrational energies. This is done in kinetic theory {both traditional and this author's [2,3]} and statistical thermodynamics. Such elastic collision mathematical structures (e.g., statistical thermodynamics) become approximations [4] whose validity can be lost in our open-system inelastic-collision reality.

Although, a system's total radiative energy remains comparatively minute, one should not disregard its existence when contemplating heat transfer. This is due to photons travelling at the speed of light, while gas molecules tend to possess non-relativistic speeds. Therefore, over a given duration a system's radiation heat transfer can be significant [4,5].

The applicability of temperature requires a scale, e.g., Celsius scale. This enables temperature to be a variable in relations that determine a gaseous system's energy, e.g., the ideal gas law, or kinetic theory. The uniformity determined in closed system experiments implies that their measured temperatures are isotropic.

A directional thermometer may read different temperatures dependent upon the direction that the thermometer is pointed, i.e., anisotropic temperature. This is often associated with anisotropic flows of matter, such as those that are dealt with in plasma physics [9].

As long as the relationship between temperature and the system's thermal energy remains a linear function then a standard non-directional thermometer, e.g., a dry-bulb (mercury) thermometer, will measure an average temperature that can be used to calculate the average energy associated with the anisotropic flow.

Accepting that molecular collisions (both inter and intra) result in photons is one thing. To be part of a system's thermal energy, such photons must also be absorbed by atoms/molecules. Interestingly, Allmendinger's [10] experimental results can best be explained in terms of photons passing their momentum onto molecules, i.e., wave-particle duality in radiative heat transfer [5].

Photons that pass their momentum onto matter can be contemplated as thermal photons. Such momentum (hence energy) is readily absorbed into the vibrational energies (phonons) within either polyatomic gases or condensed

matter [4]. Note that a directed stream of thermal photons can result in increases to both the translational and rotational energy of gas molecules, as witnessed in Allmendinger's experiments [4,10].

An example of an open system, whose measured temperatures are often suspicious is Earth's atmosphere, which can be divided into several layers based upon their temperature gradients [11], as follows:

Troposphere: Its temperature decreases with increasing elevation. Approximate temperature range: T < 20 °C at sea level to -70 °C at tropopause. The environmental lapse rate defines how the temperature decreases with elevation in troposphere, e.g., 6.5 °C/km. The majority of the atmosphere's matter resides here, and this is where Earth's weather occurs.

Stratosphere: Its temperature increases with increasing elevation. Approximate temperature range: -51 °C < T <-15 °C.

Mesosphere: Its temperature decreases with increasing elevation. Approximate temperature range: -120 °C at the mesopause to T < 0 °C at the stratopause.

Thermosphere: Its temperature increases with increasing elevation. Approximate temperature range: -120 °C < T < 2000 °C.

There is no universal explanation for the four layer's differing temperature gradients. The accepted justification for the stratosphere's positive temperature gradient is based upon ozone (O_3) absorbing our Sun's UV radiation [11,12]. Certainly, ozone can absorb a thermal photon's momentum in a manner that is similar to other triatomic gases, i.e., absorption of a photon's momentum is not unique to O_3 [4]. This is not to claim that ozone plays no role in elevating the stratosphere's temperature. Nor is it to claim that O_3 does not absorb UV frequencies.

Rather, a broad simple explanation may exist based upon the differences between kinematic vs radiative heat transfer and their relations to temperature. This requires significant challenges to accepted doctrine.

2. Closed System Thermal Equilibrium

Consider a closed system, e.g., an experimental system. If both the dilute gas and its surrounding walls are in thermal equilibrium at T, as illustrated in Fig. 1, then isothermal means that:

The walls are in thermal equilibrium with the enclosed blackbody radiation, i.e., radiation energy flux in equals radiation energy flux out.

The gas molecule's kinematic energies are in thermal equilibrium with the wall's molecule's vibrations [2,3], i.e., kinematic energy flux in equals kinematic energy flux out.

The gas molecule's vibrational energy is in thermal equilibrium with the enclosed blackbody radiation, i.e., radiative energy flux into the gas molecules equals their radiative energy flux out.

As discussed, not only do the closed system's walls impose their kinematics onto the enclosed gas molecules [2,3], but they also recycle the radiation energy, thus creating the illusion of elastic collisions [4]. Thus explaining why in closed systems, $T=T_w=T_g=T_r$ where the subscripts w,g, and r respectively represent the walls, gas molecules and radiation.

It is the recycling of thermal energy by the closed system's walls that allows for the system's radiation energy to be coupled to its kinematic energy. It is this coupling that allows for the illusion of elastic collisions, hence the validity of statistical thermodynamics as an approximation.

3. Vacuum's Temperature

Consider a thermometer in an enclosed vacuum, as shown in Fig 2. The thermal energy exchange is one in which the thermometer absorbs thermal radiation into its molecular vibrations, while it radiates blackbody radiation back into its surroundings. When the flux of thermal radiation into the thermometer equals that out, then the thermometer is in thermal equilibrium with its surrounding. Thus, the thermometer's reading is the temperature associated with its surrounding radiation.

If the closed vacuum is sufficiently large then any matter placed into that vacuum will attain the characteristics of matter at that temperature, e.g., a thermometer will register a temperature. If that enclosed radiation is isotropic and blackbody, then its associated temperature can be mathematically obtained by considering the Stefan-Boltzmann equation and taking the fourth root, i.e., the associated temperature being:

$$T = \sqrt[4]{\rho_B/a} \qquad (1)$$

where "ρ_B" is the blackbody energy density, and "a" is the blackbody radiation constant ,i.e., $a = 8\pi^5 k^4/15c^3h^3$. This is not temperature in the sense/scale of temperature associated kinematics. When the radiation is anisotropic, then eq 1 must be questioned.

Consider, a directional thermometer measuring an anisotropic radiation. The measured temperature will depend upon the direction that one points the thermometer. If one takes a series of measurements and then tries to determine an average temperature, one will obtain a non-sensible value. This is due to eq 1 relating temperature to the fourth root. For example, take 2, and 4 as two directional measurements. The average is 3. If one takes the fourth power of those temperatures, and then takes the average (16+256)/2 = 136. Certainly, $\sqrt[4]{136} \neq 3$. Such non-sensibility must exist in all directional temperature measurements associated with anisotropic radiation.

Even a dry-bulb thermometer surrounded by anisotropic radiation will render a non-sensible result. Assume that conduction in a dry-bulb thermometer enables its mercury contents to be approximately isothermal, thus the mercury radiates an isotropic blackbody spectrum. The thermometer's reading would be some average value but this too is non-sensible. Again, averaging the measured spectrum (T to the fourth), followed by taking the fourth root of that average, is not the same as calculating each temperature associated with each measured flux in each direction and then calculating its average temperature.

Obviously, in order to determine an associated temperature based upon eq 1, the radiation must be blackbody and isotropic. This limits any conceptualization of associated temperature to closed systems where isotropic blackbody spectrums do exist, e.g., a Jeans' cube. Anisotropic thermal radiation hence non-sensible temperature measurements become common place in low-density open systems, e.g., atmospheric physics (notably the upper atmosphere).

4. Decoupling of Measured Temperatures in Open Systems

In open systems, photons can readily vanish into one's horizon [4,5]. Thus, the validity of approximations based upon closed system experimentation quickly disappears. Thermal equilibrium between a thermometer and its surroundings still involves a combination of kinematic and radiative heat transfer.

In Fig. 3, the diatomic gas' kinematic energies dominate the atmosphere's temperature measurement. In thermal equilibrium the total kinematic energy flux absorbed by the thermometer equals the total kinematic energy flux given by the thermometer back into its surrounding gas molecules. Although radiation energy is also exchanged, it remains diminutive. Thus, as a rough

approximation, traditional notions of temperature and its association with energy still may apply. Thus, in open systems the temperature associated with radiation can decoupled from that associated with kinematics.

5. Our Atmosphere's Radiation Based Temperatures

As a gas' density decreases there will be a point where the temperature measurement becomes dominated by some spectrum of thermal photons, as illustrated in Fig. 4. Thermal equilibrium implies that the total energy flux of the absorbed thermal photons equals that radiated by the thermometer. The thermal radiation absorbed by the thermometer may, or may not be blackbody, e.g., our Sun's thermal photons might only consist of some flux of longer wavelength photons, e.g., as illustrated in Fig. 5. Conversely, the thermal photons radiated by a thermometer will be a blackbody spectrum whose peak is in the infrared, as sketched in Fig.6.

If both the absorbed and radiated spectrums are isotropic blackbody, then the energy fluxes at various wavelengths for the absorbed and radiated spectrums should be similar. In which case the measured temperature can be related to eq 1. Again, this happens in closed systems. In the open systems, e.g., our atmosphere, when the absorbed radiation is not a complete blackbody spectrum, as shown in Fig. 5, then one questions its association to temperature.

Generally, the temperature associated with our atmosphere's radiative thermal energy is decoupled from its temperature associated with kinematic energy, i.e., $T_g \neq T_r$. If a thermometer only exchanged kinematic energy with its surroundings (as traditionally claimed), then there should be a continuous measured temperature decrease with increasing atmospheric elevation. This would primarily be due to two factors:

1) The thermal radiation density emanating from Earth's surface decreasing with increasing elevation, hence the amount of thermal energy absorbed by the atmosphere's polyatomic gases decreases with altitude
2) The pressure decreases with increasing altitude, hence the temperature associated with the *P-T* relationship decreases with altitude.

6. Consideration of the Atmosphere's Temperature Gradients

Near Earth surface temperature measurements are dominated by kinematic heat transfer. As the elevation increases, the atmosphere's density decreases.

So too does the importance of radiation heat transfer, i.e., kinematic heat transfer becomes less relevant with increasing elevation. Thus, as the atmosphere's density decreases the concept of thermal equilibrium changes.

One might make the following assertions concerning Earth's atmosphere's temperature gradients as shown in Fig. 7:

Troposphere: Negative temperature gradient is due to its temperature measurements being dominated by kinematic energy fluxes as previously stated in 1) and 2).

Tropopause: Constant temperature measurements are due to a combination of radiative and kinematic energy fluxes. Note that, others have determined that the 0.1 Bar pressure at the tropopause is the location where "a temperature profile that is controlled by the absorption of short-wave solar radiation, from a region below" (troposphere)[13]. Does this now imply that the 0.1 bar marks the point where radiation energy is on the same scale as kinematic energy in an atmosphere? Note that "no explanation exists" [13] for the tropopause which is sometimes referred to as the radiative-convective boundary

Stratosphere: Positive temperature gradient is due to temperature measurements increasingly becoming influenced by the radiation energy, which primarily emanates from both Earth and its troposphere. It is a case of diminishing kinematic energy flux, in comparison to the radiation energy flux. Note that thermal radiation must have a higher associated temperature, i.e., the gas molecule's (kinematic dominated) colder measured temperatures vs some warmer measured temperature associated with the surrounding radiation's energy.

Stratopause: Constant temperature measurements are due to a fairly constant radiation energy flux.

Mesosphere: Negative temperature gradient could be due its temperature measurements being dominated by its radiation energy. Arguably the decreasing measured temperature with elevation may be due to the decreasing thermal radiation flux emanating from the troposphere, tropopause, stratosphere, stratopause and the Earth's surface. This may also necessitate that the density of thermal photons emanating from the Sun has significantly decreased, i.e., most have been absorbed by the matter (primarily gases and charged particles) in the hundreds of km of the thermosphere.

Mesopause: Constant temperatures measurements are dominated by radiative energy fluxes. Again, the thermal photon energy density must be fairly constant, as indicated by constant T. Its temperature is due to a

combination of the thermal photons radiating downwards from our Sun and thermal photon radiating upwards from below.

Thermosphere: Positive temperature gradient is due to its temperature measurements being dominated by the anisotropic radiation energy flux from our Sun. Measured temperatures (non-sensible?) increase with elevation.

The above is based upon measurements made in the daylight. At night radiation energy diminishes, hence measured temperatures should dramatically decrease. Obviously, the notion of temperature differs between the various atmospheric layers and with the diurnal cycle.

7. *P-V-T* Relationships

The ideal gas law approximates the mechanical parameters (P,V) to temperature (T) in sufficiently-dilute closed systems. If traditional concepts of temperature do not readily apply to Earth's atmosphere, then what about the ideal gas law? It is this author's assertion that the relationship between the mechanical parameters in atmospheric physics should be founded upon the following polytropic equation, which has no theoretical foundation. In terms of the polytropic exponent (n), and the proportionality constant (C):

$$PV^n = C \qquad (2)$$

The ideal gas law becomes the rare open system case of, $n = 1$.

Pressure-temperature relations are not readily understood in an elastic collision founded science. In inelastic collisional based sciences, heat is created with every collision. One can choose to think in terms of friction between molecules resulting in phonons (molecular dissipation), or in terms of inelastic collisions creating photons. Either way: $P \uparrow, T \uparrow$. In atmospheric physics, this applies more to the troposphere than any other layer.

8. Future Experimentation

Understanding the extent that various wavelengths can be considered as thermal photons requires further investigation. If one compares the Sun's irradiance at the top of the atmosphere to that at sea level, one notices a decline in energy flux at most all wavelengths. This in part seemingly indicates the absorption of at least some of our Sun's photon's momentum. A wavelength dependence is expected hence research is needed to determine a

photon's size as a function of wavelength, and how photons interact with the atmosphere's homonuclear diatomic gases. This is different than photons acting as waves, where absorption is attributed to atmospheric gas' lopsided charge distributions, as are often determined with infrared spectrometers [5].

Conclusions

One with vested interests readily forgets that more than one theory can explain a given result. Traditional thermodynamics remains founded upon sufficiently-dilute closed systems where the illusion of elastic collisions exists. In such systems (e.g., experimental systems), kinetic theory and statistical thermodynamics render good approximations. Furthermore, closed system's walls recycle both its radiation and kinematic energy, thus reenforcing the illusion. Isothermal now means that both the system's kinematic and radiative energies are relatable to the same temperature.

When applied to open systems, a science based upon closed system experimentation often loses its validity. In open systems, the concept of isothermal loses its structure when the temperature associated with the system's kinematic energy decouples from that associated with the system's radiative energy. This can be viewed in terms of how the energy associated with closed systems differs from that in open systems. Moreover, any relationships for temperature founded upon closed system experimentation become at best, rough approximations for open systems.

A vacuum's temperature can be measured with a thermometer, so long as the surrounding blackbody temperature is isotropic, as often occurs in closed systems. In such systems, a vacuum's temperature can be determined from temperature associations with the Stefan-Boltzmann equation. In open systems, the surrounding radiation often is anisotropic, e.g., Earth's upper atmosphere.

In anisotropic radiation dominated systems, any association with temperatures is often non-sensible. Importantly non-sensible temperature measurements may help one to understand the differing temperatures found in Earth's atmosphere.

The various atmospheric layers are separated by their differing temperature gradients. These differences can be explained in terms of kinematic versus radiative heat transfer, and how this will influence one's temperature reading.

The troposphere's energy is dominated by its kinematic energies (translational, rotational and vibrational energies). Temperature measurements

in the troposphere decrease with elevation as the gas molecule's kinematic energy decreases with elevation.

The stratosphere's temperature increases with elevation. This may be best explained in terms of a decreasing density of the relatively cold gas molecules, combined with a comparatively constant (but also decreasing) temperature associated with the thermal radiation that emanates from the Earth and its thermosphere. The stratosphere represents the change from the dominate kinematic heat transfer to the domination by radiative heat transfer.

The temperature in the mesosphere decreases with elevation. This may be explainable in terms of diminishing thermal radiation emanating from the Earth, troposphere and stratosphere. Conversely, the temperature increases with elevation in the thermosphere. This can be explained in terms of the anisotropic thermal radiation from our Sun, explaining its non-sensibility.

Consideration by other like-minded individuals should lead to new insights.

Figures

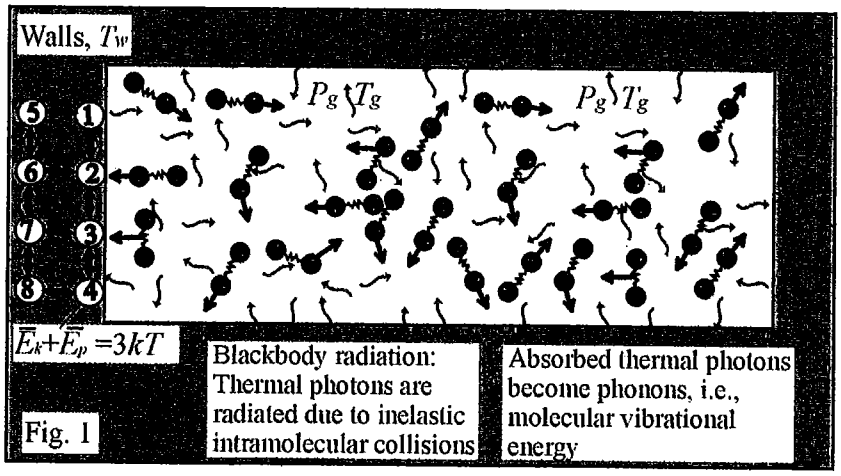

Fig. 1 shows the kinematic and radiative energy in a closed system of polyatomic gas. Kinematic energy exchange involves the walls imposing their vibrational energies onto the enclosed gas molecules. Radiative energy exchange involves blackbody radiation emitted by the walls and gas molecules. Thermal photons are absorbed by the walls and polyatomic gases. Importantly: $T=T_w=T_g=T_r$.

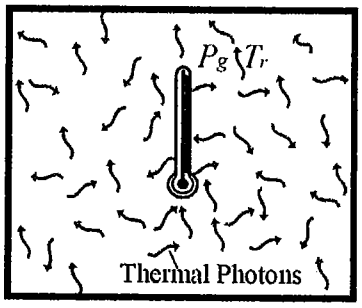

Fig. 2

Fig. 2 shows a thermometer in an enclosed system filled with isotropic blackbody radiation, e.g., a Jeans' cube. Importantly: $T=T_w=T_r$. .

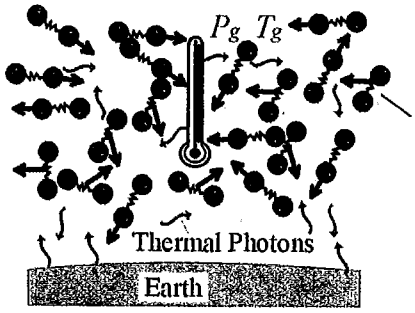

Fig. 3

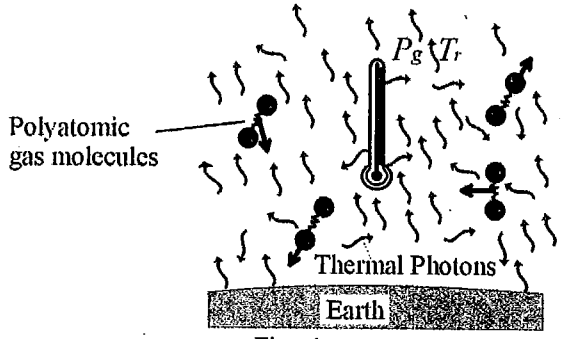

Fig. 4

Fig. 3 shows a diatomic gas at a moderate pressure (P_g) surrounding a thermometer. The gas' kinematic energy dominates a temperature measurement (T_g). The thermometer also absorbs thermal photons and radiates a blackbody spectrum, but this energy exchange is minute when compared to the kinematic energy exchange.

Fig. 4 shows a diatomic gas at a low pressure (P_g) surrounding a thermometer. Anisotropic radiation dominates a temperature measurement (T_r), i.e., the thermometer absorbs thermal photons while radiating a blackbody spectrum. The thermometer also exchanges kinematic energy with the surrounding gas molecules but this exchange is minute when compared to the exchange of radiation energy.

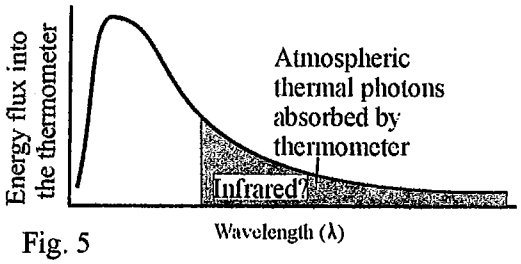

Fig. 5

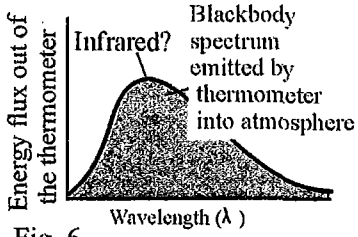

Fig. 6

Fig. 5 shows the thermal photons primarily consisting of the longer wavelength of a blackbody spectrum, e.g., the infrared portion of our Sun's blackbody curve.

Fig. 6 shows a blackbody spectrum that is radiated by a thermometer into its surroundings, e.g., a blackbody spectrum whose peak is in the infrared.

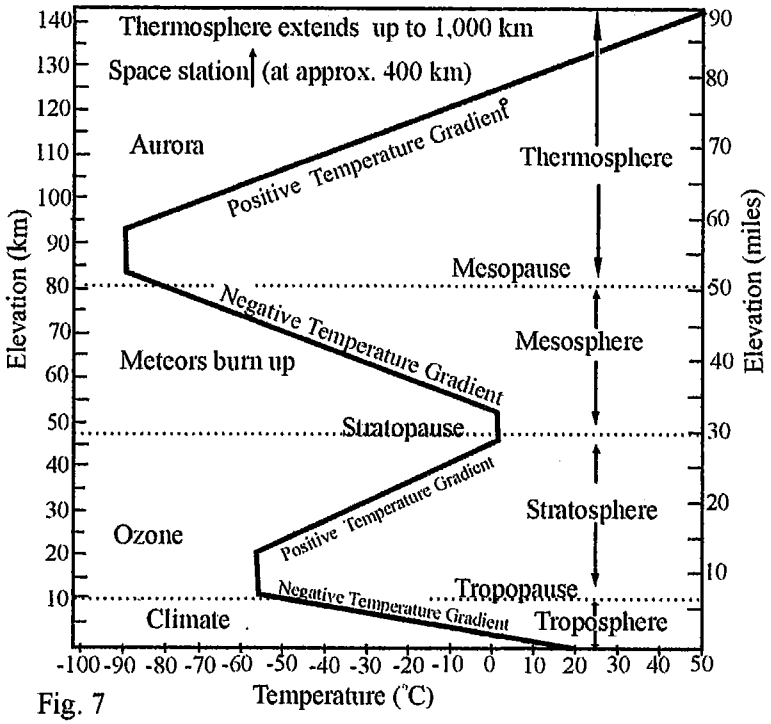

Fig. 7

Fig. 7 is a typical mid latitude temperature profile for Earth's atmosphere. Sketch based upon NASA [11].

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INDEX
HADRONIC JOURNAL, VOLUME 44, 2021

ANALYTIC DISTORTED – WAVE APPROXIMATION FOR NUCLEONS QUASI – ELASTIC SCATTERING CALCULATIONS, 1
Mirteymur Mirabutalybov
Physics Department,
Azerbaijan State Oil and Industrial University
Baku, Azerbaijan
DISTORTED-WAVE APPROXIMATION THEORY FOR ELECTRON SCATTERING FROM ATOMIC, 19
Mirteymur M.M. and Resulova A.V.
Physics Department
Azerbaijan State Oil and Industrial University
Baku, Azerbaijan
MULTIPLE PARTON SCATTERING AT HIGH ENERGY PROTON-PROTON COLLISIONS, 27
M.Y. Hussein
Department of Physics, University of Bahrain
P.O. Box 32038, Kingdom of Bahrain and
Search Center, Shaikh Ebrahim Bin Mohammed
Al Khalifa Center for Culture and Research
P.O. Box 13725, Muharraq, Kingdom of Bahrain
HEAT MASS TRANSFER OF NANOFLUIDS FLOW WITH ABSORPTION IN THE PRESENCE OF THERMAL RADIATION, 35
S.Y. Zayyanu, I.J. Uwanta and M.M. Hamza
Department of Mathematics
Usmanu Danfodiyo University
Sokoto, Sokoto, Nigeria
NEW THERMODYNAMICS: INELASTIC COLLISIONS, LOST WORK, AND GASEOUS INEFFICIENCY, 67
Kent W. Mayhew
68 Pineglen Cres.
Ottawa, Ontario, Canada, K2G 0G8
CALCULATION OF THE EXACT RANGE OF THE MASS OF HIGGS BOSON IN THE LARGE HADRON COLLIDER (LHC) ON THE BASIS OF THE QUANTIZED SPACE AND TIME THEORY, 97
Hamid Reza Karimi
Electrical Engineering Department, Islamic Azad University
South Tehran Branch, Tehran, 17776-13651, Iran

QUANTUM AND CLASSICAL UNIVERSE AND ANTI-UNIVERSE, 109
H. Strusny
Hohenschoenhauser Str. 1
10369 Berlin, Germany
ADDITIONAL CONSERVED QUANTITIES OF WEBER'S FORCE LAW?, 169
Alan Aversa
ANOMALOUS MAGNETIC MOMENTUM OF MUONS IN FNAL ON THE BASIS OF QUANTIZE SPACE AND TIME THEORY, 181
Hamid Reza Karimi
Electrical Engineering Department
Islamic Azad University, South Tehran Branch
Tehran, 17776-13651, Iran
HOW AND WHY THE DECAY MODES OF BEAUTY QUARKS INTO LEPTONS DECAY IN LHCb ON THE BASIS OF THE QUANTIZED SPACE AND TIME THEORY, 193
Hamid Reza Karimi
Electrical Engineering Department
Islamic Azad University, South Tehran Branch
Tehran, 17776-13651, Iran
EFFECTIVE POTENTIAL OF MUONIC AND TAUONIC ATOMS OF HELIUM AND HELIUM LIKE ATOMS, 201
Saddam Husain Dhobi
Department of Physics, Patan Multiple Campus
Tribhuvan University, Lalitpur-44700, Nepal
Robotics Academy of Nepal, Lalitpur-44700, Nepal
Innovative Ghar Nepal of Nepal, Lalitpur-44700, Nepal
NEW THERMODYNAMICS: WAVE-PARTICLE DUALITY IN RADIATIVE HEAT TRANSFER, 215
Kent W. Mayhew
68 Pineglen Cres.
Ottawa, Ontario, Canada
THE HELIX CURVES ON THE SPHERES OF LORENTZ-MINKOWSKI SPACE R^3_1, 227
H. H. Ugurlu
Gazi University, Faculty of Education
Department of Secondary Education Science and Mathematics Teaching
Mathematics Teaching Program, 06560, Ankara, Turkey
V. Bulut
Department of Engineering Sciences, Izmir Katip Celebi University
Izmir, Turkey
M. Aydinalp
Manisa Celal Bayar University, Faculty of Arts and Sciences
Department of Mathematics, 45140, Manisa, Turkey

MATRIX, GROUP, TENSOR, ETC., AND CORRESPONDING MATHEMATICAL QUANTUM THEORY AND ITS APPLICATIONS, 251
Yi-Fang Chang
Department of Physics
Yunnan University
Kunming, 650091, China
THE QUANTIZATION EFFECT AND THE HARMONIC OSCILLATOR, 269
Patrick Cornille
Retired Physicist from the C.E.A.
Advanced Electromagnetic Systems
7 Rue de la Perdriere
59320 Ennetieres-en-Weppes, France
EXAMINING A SURFACE BASED ON A DEVELOPABLE RULED SURFACE, 293
V. Bulut
Department of Engineering Sciences,
Izmir Katip Celebi University, Cigli, Izmir, 35620, Turkey
A. Caliskan
Department of Mathematics, Kirklareli University
Kayali, Kirklareli, 39100, Turkey
TOPOLOGICAL STRUCTURES IN PARTICLES AND SPIN HYPOTHESIS, 311
Yi-Fang Chang
Department of Physics
Yunnan University
Kunming, 650091, China
INTERPRETATION OF GRAVITY, 329
Bertrand Wong
Department of Science and Technology
Eurotech, Singapore Branch
EXPANSION FORCE AS A CONSEQUENCE OF BOHMIAN QUANTUM MECHANICS, 343
Jacques Fleuret
Telecom Paris Tech
33 rue des Roses
92160 Antony, France
NEW RESEARCH AND DEVELOPMENT OF UNCERTAINTY RELATIONS, 357
Yi-Fang Chang
Department of Physics
Yunnan University
Kunming, 650091, China

THE RELATIONSHIP OF DENSITY WITH THE SIZES OF ATOMS AND THEIR NUCLEI, 379
F. F. Gorbatsevich
Geological Institute of the Kola Science
Centre of the Russian Academy of Sciences, Apatity
TIME AND THE QUANTUM PART 1; TIME-ONLY PHYSICS, 387
Graham Andrews
15924 N. Azure Dr.
Spokane, Washington 99208
TIME AND THE QUANTUM PART 2; WHENCE THE QUANTUM?, 409
Graham Andrews
15924 N. Azure Dr.
Spokane, Washington 99208
NEW THERMODYNAMICS: QUESTIONING TEMPERATURE IN OPEN SYSTEMS, e.g., IN ATMOSPHERIC PHYSICS, 431
Kent W. Mayhew
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Ottawa, Ontario, Canada K2G 0G8

INDEX VOL 44, 2021.....445